International Conference on Applied Mathematics 2012: Modeling, Analysis and Computation

28 May — 1 June 2012, City University of Hong Kong

Program and Abstracts

Contents

WELCOMING MESSAGE

Welcome to City University of Hong Kong for the *International Conference on Applied Mathematics 2012: Modeling, Analysis and Computation (ICAM 2012)*.

The first International Conference on Applied Mathematics: Modeling, Analysis and Computation was held in June 2008. The second International Conference on Applied Mathematics was held in June 2010. Following the same tradition of the previous two conferences, the ICAM 2012 provides a forum for exchanging ideas and in-depth discussions on different aspects of applied mathematics, including analysis, computational methods, and applications.

The second William Benter Prize in Applied Mathematics will be awarded. We are very honored to have Mr William Benter to award the Prize to the recipient. The aim of the Prize is to recognize outstanding mathematical contributions that have had a direct and fundamental impact on scientific, business, finance, or engineering applications.

The 5-day conference consists of plenary lectures, invited talks and contributed talks, it brings together local and overseas researchers with diverse backgrounds. We believe you will find many talks of interests. We also hope that you will take time to explore the city of Hong Kong, one of the most exciting metropolises in Asia Pacific. Wish you a most enjoyable stay!

Organizing Committee

Hui-Hui Dai
City University of Hong Kong

Ya Yan Lu
City University of Hong Kong (Chair)

Weiwei Sun
City University of Hong Kong

Qiang Zhang
City University of Hong Kong

Ding-Xuan Zhou
City University of Hong Kong

Conference Coordinator

Sophie Xie
Liu Bie Ju Centre for Mathematical Sciences, City University of Hong Kong

GENERAL INFORMATION

Registration Desk

Date: 27 to 31 May (Sunday to Thursday)
Time: 18:30 - 21:00 (Sunday, 27 May) – Early Registration
08:30 - 09:00 (Monday, 28 May)
08:30 - 09:00 (Tuesday, 29 May)
08:45 - 09:00 (Wednesday, 30 May)
08:45 - 09:00 (Thursday, 31 May)

Early registration will be available at the Welcoming Reception on 27 May, from 18:30 – 21:00 at the Staff Lounge, City Top Restaurant located at 9/F, Amenities Building, CityU.

Conference Venue

Plenary Sessions

Lecture Theatre 18 (LT-18): 4/F, Academic 1, CityU

Parallel Sessions

Classrooms P4701, P4703 and P4704 (Purple Zone): 4/F, Academic 1, CityU

LT-18 and classrooms are equipped with a desktop computer, a cable for connecting to laptop, an overhead projector and white boards.

Social Events

Welcoming Reception

Date: 27 May (Sunday)
Time: 18:30 to 21:00
Venue: Staff Lounge, City Top Restaurant at 9/F, Amenities Building, CityU

It is open to all participants of the conference. An "Early Registration" desk will be installed at this venue.
Please refer to page 5 for directions to the restaurant.

Conference Banquet

Date: 30 May (Wednesday)
Time: 18:00 to 21:00
Venue: Staff Lounge, City Top Restaurant, 9/F, Amenities Building, CityU.

HK$300 per person (Prior registration is required.)
Please refer to page 5 for directions to the restaurant.

Group Photo

Date: 28 May (Monday)
Time: 12.00 noon
Venue: University Circle (located outside the Academic 1).

OTHER INFORMATION

Name Badges

All attendees are requested to wear their name badges. Members of the organizing committee and conference assistants are ready to assist you if needed.

Banking Service

Opening Hours: 09:00 to 17:00 (Monday to Friday)
The Hang Seng Bank at CityU is located next to Run Run Shaw Library at 3/F, Academic 1. Foreign currency exchange service is provided and travelers cheques can be cashed.

Message Board

Message boards are located outside Lecture Theatre 18 (LT-18). Latest information of the conference and messages for attendees will be posted on these boards.

Computer and Internet Services

Networked computers are available at Mathematical Laboratory during the conference period:

Date: 28 May – 1 June 2012 (Monday to Friday)
Time: 09:00 to 18:00
Venue: Y6504, 6/F, Academic 1, Yellow Zone (near lift 9)

Wireless internet access through your own mobile device within CityU campus is also available. A login name and password will be distributed during registration.
If you wish, you could also approach our conference assistants for MAC address registration. One day is required for our Computer Service Centre to process your application.

Fax Services

Fax messages can be received at +852 3442-0250. Please quote "ICAM 2012" and state clearly the names of recipients.

Useful Telephone Numbers

CityU Campus

General line:	+852 3442 7654
LBJ Centre:	+852 3442 9816 / 3442 6570
Health Centre:	+852 3442 6066
Security Office:	+852 3442 8888
Wong Fong Ling Hall:	+852 3442 8833 / 2777 0190
Guest Quarter:	+852 3442 1200

Hotels

Harbour Plaza Metropolis Hotel:	+852 3160-6888 / 3160-6807
Royal Plaza Hotel:	+852 2928 8822 / 2622 6291
Metropark Hotel Mongkok:	+852 2397 6683 / 2397 9668

MISC

Immigration Department:	+852 2824 6111
Hong Kong Police:	999

ACKNOWLEDGEMENTS

We gratefully acknowledge the generous support of the following organizations and institutions for the conference.

Department of Mathematics, City University of Hong Kong

K. C. Wong Education Foundation

Hong Kong Mathematical Society

Liu Bie Ju Centre for Mathematical Sciences, City University of Hong Kong

PROGRAM AT A GLANCE

Sunday, 27 May 2012

Venue: Staff Lounge, City Top Restaurant
18.30–21.00
Welcoming Reception and Registration*

Location:
Staff Lounge, City Top Restaurant, 9/F, Amenities Building, City University of Hong Kong.
*Registration will also be available from Monday to Thursday during the conference.

Monday, 28 May 2012

Venue: LT-18		
08.30–09.00		
Registration		
09.00 Opening Ceremony		
Opening Speech – Roderick WONG		
09.00–09.30		
Presentation of the William Benter Prize in Applied Mathematics Prize awarded by William Benter *Chair: Roderick WONG*		
09.30–10.30		
Plenary I (William Benter Prize Lecture): James D. MURRAY *Chair: Philip MAINI*		
10.30–11.00 Coffee Break		
11.00–12.00		
Plenary II: George PAPANICOLAOU *Chair: Ding-Xuan ZHOU*		
12.00–12.20 Photo Session		
12.20–14.00 **Lunch**		
Venue: LT-18 14.00–15.00		
Plenary III: Chi–Wang SHU *Chair: Xiao-Ping WANG*		
15.00–15.30 Coffee Break		
Venue: P4701 *DG and WENO Methods I* *Chair: Chi–Wang SHU*	**Venue: P4703** *William Benter Prize Minisymposium* *Chair: Philip MAINI*	**Venue: P4704** *Dynamical Systems* *Chair: Kwok Wai CHUNG*
15.30–16.00	15.30–16.00	15.30–15.50
Ching-Shan CHOU	Paul KULESA	Shyan-Shiou CHEN 15.50–16.10 Jui-Pin TSENG
16.00–16.30	16.00–16.30	16.10–16.30
Fengyan LI	Mary MYERSCOUGH	Yancong XU
16.30–17.00	16.30–17.00	16.30–16.50
Jennifer RYAN	Jonathan SHERRATT	Xuxin YANG
17.00–17.30	17.00–17.30	
Yinhua XIA	Jane WHITE	

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

Tuesday, 29 May 2012

Venue: LT-18
08.30–09.00 Registration
09.00–10.00
Plenary IV: Alexandre J. CHORIN *Chair: Qiang ZHANG*
10.00–10.30 Coffee Break

Venue: P4701 *DG and WENO Methods II* *Chair: Fengyan LI*	**Venue: P4703** *Mathematical Biology I* *Chair: David CAI*	**Venue: P4704** *Linear and Nonlinear Waves* *Chair: Xiang ZHOU*
10.30–11.00 Yan XU	10.30–11.00 Anita LAYTON	10.30–10.50 Annette WORTHY 10.50–11.10 Zhen HU
11.00–11.30 Mengping ZHANG	11.00–11.30 Paul J. ATZBERGER	11.10–11.30 Jonathan SHERRATT
11.30–12.00 Zhengfu XU	11.30–12.00 Saverio SPAGNOLIE	11.30–11.50 Wangtao LU 11.50–12.10 Roman BRIZITSKII
12.00–12.30 Yulong XING	12.00–12.30 Dan HU	12.10–12.30 Shichang SHE

12.30–14.00 **Lunch**
Venue: LT-18 14.00–15.00
Plenary V: James DEMMEL *Chair: Qiang YE*
15.00–15.30 Coffee Break

Venue: P4701 *Numerical Linear Algebra I* *Chair: Qiang YE*	**Venue: P4703** *Computational Fluid Dynamics I* *Chair: Xiao-Ping WANG*	**Venue: P4704** *Mathematical Modeling I* *Chair: Laurent MERTZ*
15.30–16.00 Raymond CHAN	15.30–16.00 Jie SHEN	15.30–15.50 Ana YUN 15.50–16.10 Darae JEONG
16.00–16.30 Michael NG	16.00–16.30 Tiezheng QIAN	16.10–16.30 Fion WK CHEUNG
16.30–17.00 Xiao-Wen CHANG	16.30–17.00 Shuyu SUN	16.30–16.50 Daihai HE 16.50–17.10 Douglas KS NG
17.00–17.30 Eric King-wah CHU		

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

Wednesday, 30 May 2012

Venue: LT-18		
08.45–09.00 Registration		
09.00–10.00		
Plenary VI: Frederic Y. M. WAN *Chair: Hui-Hui DAI*		
10.00–10.30 Coffee Break		
Venue: P4701 *Numerical Analysis I* *Chair: G. FAIRWEATHER*	**Venue: P4703** *Mathematical Biology II* *Chair: Anita LAYTON*	**Venue: P4704** *Analysis and Applications* *Chair: Dan DAI*
10.30–11.00	10.30–11.00	10.30–10.50
Ian SLOAN	Dezhe JIN	Kim Tuan VU
		10.50–11.10
11.00–11.30	11.00–11.30	Tommi SOTTINEN
		11.10–11.30
Eun-Jae PARK	Douglas ZHOU	Dejun XIE
11.30–12.00	11.30–12.00	11.30–11.50
Zhonghua QIAO	Daniel FORGER	Wen-Ming HE
		11.50–12.10
12.00–12.30	12.00–12.30	Minvydas RAGULSKIS
		12.10–12.30
Kui DU	David CAI	Yen-Chern LIN
12.30–14.00 **Lunch**		
Venue: LT-18 14.00–15.00		
Plenary VII: Lloyd N. TREFETHEN *Chair: Chi–Wang SHU*		
15.00–15.30 Coffee Break		
Venue: P4701 *Computational Fluid Dynamics II* *Chair: Jie SHEN*	**Venue: P4703** *Computational Wave Propagation I* *Chair: Xavier ANTOINE*	**Venue: P4704** *Numerical Methods I* *Chair: Amiya PANI*
15.30–16.00	15.30–16.00	15.30–15.50
Weiqing REN	Timo BETCKE	Jian DENG
		15.50–16.10
16.00–16.30	16.00–16.30	Bihong CHEN
		16.10–16.30
Xiao-Ping WANG	Christophe GEUZAINE	Zhiming GAO
	16.30–17.00	16.30–16.50
	Manfred HAMMER	Chih-Wen CHANG
	17.00–17.30	
	Eric CHUNG	
18.00–21.00 Conference Banquet*		

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)
*Conference Banquet: Staff Lounge, City Top Restaurant, 9/F, Amenities Building.

Thursday, 31 May 2012

Venue: LT-18
08.45–09.00 Registration
09.00–10.00
Plenary VIII: Bjorn ENGQUIST *Chair: Gang BAO*
10.00–10.30 Coffee Break

Venue: P4701	**Venue: P4703**	**Venue: P4704**
Numerical Linear Algebra II *Chair: Xiao-Wen CHANG*	*Inverse Problems I* *Chair: Bo ZHANG*	*Mathematical Modeling II* *Chair: Daihai HE*
10.30–11.00 Zhongxiao JIA	10.30–11.00 Jin CHENG	10.30–10.50 Buyang LI
		10.50–11.10 Laurent MERTZ
11.00–11.30 Karl MEERBERGEN	11.00–11.30 Peijun LI	11.10–11.30 Chien-Hao TSENG
11.30–12.00 Jianlin XIA	11.30–12.00 Hongyu LIU	11.30–11.50 Dmitry TERESHKO
		11.50–12.10 Dilip Kumar JAISWAL
	12.00–12.30 Jiguang SUN	12.10–12.30 Atul KUMAR

12.30–14.00 **Lunch**
Venue: LT-18 14.00–15.00
Plenary IX: Philip MAINI *Chair: David CAI*
15.00–15.30 Coffee Break

Venue: P4701	**Venue: P4703**	**Venue: P4704**
Numerical Linear Algebra III *Chair: Eric King-wah CHU*	*Computational Wave Propagation II* *Chair: Timo BETCKE*	*Numerical Methods II* *Chair: Dongwoo SHEEN*
15.30–16.00 Jungong XUE	15.30–16.00 Igor TSUKERMAN	15.30–15.50 Rafael BORGES
		15.50–16.10 Antti RASILA
16.00–16.30 Zhenyue ZHANG	16.00–16.30 Shingyu LEUNG	16.10–16.30 Hyun Geun LEE
16.30–17.00 Qiang YE	16.30–17.00 Jinjie LIU	16.30–16.50 Hua ZOU
		16.50–17.10 Pankaj BISWAS
	17.00–17.30 Xavier ANTOINE	17.10–17.30 Wulan LI

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

Friday, 1 June 2012

Venue: LT-18	
09.00–10.00	
Plenary X: Gang BAO *Chair: Jun ZOU*	
10.00–10.30 Coffee Break	
Venue: P4701 *Numerical Analysis II* *Chair: Eun Jae PARK*	**Venue: P4703** *Inverse Problems II* *Chair: Jun ZOU*
10.30–11.00	10.30–11.00
Dongwoo SHEEN	Jijun LIU
11.00–11.30	11.00–11.30
Amiya PANI	Fuming MA
11.30–12.00	11.30–12.00
Da XU	Faouzi TRIKI
12.00–12.30	12.00–12.30
Graeme FAIRWEATHER	KiHyun YUN
12.30–14.00 **Lunch**	
Venue: LT-18 14.00–15.00	
Plenary X: Alan NEWELL *Chair: Jonathan WYLIE*	
15.00–15.30 Coffee Break	
Venue: P4701 *Fluid Dynamics* *Chair: Qiang ZHANG*	**Venue: P4703** *Inverse Problems III* *Chair: Jin CHENG*
15.30–16.00	15.30–16.00
Michael K.H. CHAN	Jenn-Nan WANG
16.00–16.30	16.00–16.30
Yuhui DENG	Bo ZHANG
16.30–17.00	16.30–17.00
Jonathan WYLIE	Haijun WU
	17.00–17.30
	Jun ZOU

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

PROGRAM

Sunday, 27 May 2012

18.30–21.00, Staff Lounge, City Top Restaurant
Welcoming Reception and Registration

Location:
Staff Lounge, City Top Restaurant, 9/F, Amenities Building, City University of Hong Kong.
*Registration will also be available from Monday to Thursday during the conference.

Monday, 28 May 2012

LT-18 08.30–09.00 Registration

LT-18 9.00 Openning Ceremony

Opening Speech – Roderick WONG

Plenary Talk **LT-18** 09.00–09.30 *Chaired by Roderick WONG*

Presentation of the Prize

Plenary Talk **LT-18** 09.30–10.30 *Chaired by Philip MAINI*

JAMES D. MURRAY
Modelling in the biomedical and social sciences: from animal coat patterns to brain tumours to saving marriages (abstract, page 65)

LT-18 10.30–11.00 Coffee Break

Plenary Talk **LT-18** 11.00-12.00 *Chaired by Ding-Xuan ZHOU*

GEORGE PAPANICOLAOU
Systemic risk (abstract, page 68)

12.00–12.20 Photo Session (University Circle – outside of Academic 1)

12.20–14.00 *Lunch*

Plenary Talk **LT-18** 14.00–15.00 *Chaired by Xiao-Ping WANG*

CHI-WANG SHU
Positivity-preserving high order schemes for convection dominated equations (abstract, page 74)

LT-18 15.00–15.30 Coffee Break

Parallel Session 1 *DG and WENO Methods I,* **P4701**

Chaired by Chi-Wang SHU

P4701 15.30–16.00

CHING-SHAN CHOU
Fast sweeping methods for steady state problems for hyperbolic conservation laws (abstract, page 46)

P4701 16.00–16.30

FENGYAN LI
Discontinuous Galerkin methods for Vlasov-Maxwell equations (abstract, page 59)

P4701 16.30–17.00

XIAOZHOU LI AND JENNIFER K.RYAN*
Computationally efficient position-dependent smoothness-increasing accuracy-conservering (SIAC) filtering (abstract, page 71)

P4701 17.00–17.30

YINHUA XIA
Discontinuous Galerkin methods for the nonlinear Schrödinger equation (abstract, page 84)

Parallel Session 2 *William Benter Prize Minisymposium,* **P4703**

Chaired by Philip MAINI

P4703 15.30–16.00

PAUL M. KULESA* , REBECCA MCLENNAN, JASON MORRISON, KATE PRATHER, LOUISE DYSON, MICHELLE L. WYNN, SANTIAGO SCHNELL, RUTH E. BAKER, AND PHILIP K. MAINI
Mechanisms of long distance cell migration (abstract, page 56)

P4703 16.00–16.30

MARY R MYERSCOUGH
The mathematics of choosing a new home; modelling nest site selection in honey bees (abstract, page 65)

P4703 16.30–17.00

JONATHAN A. SHERRATT
Population cycles in voles: predators, seasonality and killer grass (abstract, page 73)

P4703 17.00–17.30

JANE WHITE
Understanding the impact of public health policy: a contribution using mathematical models (abstract, page 81)

Parallel Session 3 *Dynamical Systems,* **P4704**

Chaired by Kwok Wai CHUNG

P4704 15.30–15.50

SHYAN-SHIOU CHEN* AND CHANG-YUAN CHENG
Dynamics for a two-dimensional Hindmarsh-Rose type model with four parameters (abstract, page 44)

P4704 15.50–16.10

JUI-PIN TSENG
Global asymptotic dynamics in a coupled neural network with delays (abstract, page 79)

P4704 16.10–16.30

YANCONG XU* AND BJORN SANDSTEDE
Snakes and isolas in nonreversible conservative systems (abstract, page 86)

P4704 16.30–16.50

XUXIN YANG
On existence of periodic solutions for the Duffing equation with impulses (abstract, page 87)

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

Tuesday, 29 May 2012

LT-18 08.30–09.00 Registration

Plenary Talk **LT-18** 09.00–10.00 *Chaired by Qiang ZHANG*

ALEXANDRE J. CHORIN
Implicit sampling, with applications to filtering and data assimilation (abstract, page 45)

LT-18 10.00–10.30 Coffee Break

Parallel Session 1 *DG and WENO Methods II,* **P4701**

Chaired by Fengyan LI

P4701 10.30–11.00

YAN XU
Multigrid methods of discontinuous Galerkin discretization for time-dependent fourth-order problems (abstract, page 86)

P4701 11.00–11.30

JIANG YAN, CHI-WANG SHU, AND MENGPING ZHANG*
A new formulation of finite difference WENO scheme with Lax-Wendroff time discretization for conservation laws (abstract, page 90)

P4701 11.30–12.00

ZHENGFU XU
Parameterized maximum principle preserving flux limiters for high order scheme solving hyperbolic conservation laws: one-dimensional scalar problem (abstract, page 86)

P4701 12.00–12.30

YULONG XING
Conservative discontinuous Galerkin methods for the generalized Korteweg-de Vries equations (abstract, page 85)

Parallel Session 2 *Mathematical Biology I,* **P4703**

Chaired by David CAI

P4703 10.30–11.00

Anita T. LAYTON
Modeling renal hemodynamics: how the kidney regulates blood flow (abstract, page 57)

P4703 11.00–11.30

Paul J. ATZBERGER
Stochastic Eulerian Lagrangian methods for microscopic hydrodynamics and the study of fluid-structure interactions subject to thermal fluctuations (abstract, page 38)

P4703 11.30–12.00

Saverio SPAGNOLIE* and Eric LAUGA
Hydrodynamics of self-propulsion near boundaries (abstract, page 75)

P4703 12.00–12.30

Dan HU
Optimization, adaptation, and initiation of biological transport networks (abstract, page 53)

Parallel Session 3 *Linear and Nonlinear Waves,* **P4704**

Chaired by Xiang ZHOU

P4704 10.30–10.50

A.A. MINZONI, L. W. SCIBERRAS, N. F. SMYTH, and A. L. WORTHY*
Propagation of stable nonlinear beams in a finite nematic liquid crystal cell (abstract, page 82)

P4704 10.50–11.10

Zhen HU* and Ya Yan LU
A simple boundary condition for terminating photonic crystal waveguides (abstract, page 53)

P4704 11.10–11.30

Jonathan A. SHERRATT
Calculation of periodic travelling wave stability: a users' guide (abstract, page 73)

P4704 11.30–11.50

Wangtao LU* and Ya Yan LU
Efficient boundary integral equation method for photonic crystal fibers (abstract, page 63)

P4704 11.50–12.10

G. ALEKSEEV AND R. BRIZITSKII*
The control problems for time–harmonic Maxwell and Helmholtz equations (abstract, page 41)

P4704 12.10–12.30

SHICHANG SHE* AND YA YAN LU
Perfectly matched layers conforming to triangular lattices for numerical simulations of photonic crystal devices (abstract, page 72)

12.30–14.00 *Lunch*

Plenary Talk **LT-18** 14.00–15.00 *Chaired by Qiang YE*

JAMES DEMMEL
Minimizing communication (abstract, page 47)

Parallel Session 1 *Numerical Linear Algebra I,* **P4701**

Chaired by Qiang YE

P4701 15.30–16.00

XIAOHAO CAI, RAYMOND CHAN*, AND TIEYONG ZENG
Image segmentation by convex approximation of the Mumford-Shan model (abstract, page 42)

P4701 16.00–16.30

MICHAEL K. NG
SNMFCA: supervised NMF-based image classification and annotation (abstract, page 67)

P4701 16.30–17.00

XIAO-WEN CHANG
Two floating point LLL lattice reduction algorithms (abstract, page 43)

P4701 17.00–17.30

ERIC KING-WAH CHU
Structured solution of large-scale nonlinear matrix equations (abstract, page 46)

Parallel Session 2 *Computational Fluid Dynamics I,* **P4703**

Chaired by Xiao-Ping WANG

P4703 15.30–16.00

JIE SHEN
Some recent advances on phase-field models for multiphase complex fluids (abstract, page 72)

P4703 16.00–16.30

TIEZHENG QIAN
Droplet motion in one-component fluids on solid substrates with wettability and temperature gradients (abstract, page 69)

P4703 16.30–17.00

SHUYU SUN
Simulation of flow and transport in subsurface carbon sequestration using conservative finite element methods (abstract, page 76)

Parallel Session 3 *Mathematical Modeling I,* **P4704**

Chaired by Laurent MERTZ

P4704 15.30–15.50

ANA YUN* AND JUNSEOK KIM
A phase-field model for tissue regeneration in a cartilage-hydrogel model (abstract, page 88)

P4704 15.50–16.10

DARAE JEONG*, ANA YUN, AND JUNSEOK KIM
Mathematical analysis of cell growth within tissue-engineering scaffolds (abstract, page 54)

P4704 16.10–16.30

FION WK CHEUNG* AND DOUGLAS KS NG
Mathematical modelling of tumor growth (abstract, page 45)

P4704 16.30–16.50

DAIHAI HE*, JONATHAN DUSHOFF, TROY DAY, JUNLING MA, AND DAVID EARN
Investigating the causes of the three waves of the 1918 influenza pandemic in England and Wales (abstract, page 52)

P4704 16.50–17.10

DOUGLAS KS NG*, SM WONG, AND FION WK CHEUNG
Deformable image registration algorithm for intensity modulated radiation therapy(IMRT) (abstract, page 66)

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

Wednesday, 30 May 2012

LT-18 08.45–09.00 Registration

Plenary Talk **LT-18** 09.00–10.00 *Chaired by Hui-Hui DAI*

FREDERIC Y.M. WAN
Robustness of biological tissue patterning (abstract, page 80)

LT-18 10.00–10.30 Coffee Break

Parallel Session 1 *Numerical Analysis I,* **P4701**

Chaired by Graeme FAIRWEATHER

P4701 10.30–11.00

IAN H SLOAN
Multiscale approximation with compactly supported RBFs (abstract, page 74)

P4701 11.00–11.30

EUN-JAE PARK
New hybrid discontinuous Galerkin methods (abstract, page 68)

P4701 11.30–12.00

ZHONGHUA QIAO
Energy stability analysis and adaptive time-stepping strategy for nonlinear diffusion equations (abstract, page 69)

P4701 12.00–12.30

KUI DU
Preconditioning techniques for the electromagnetic scattering from a large cavity (abstract, page 49)

Parallel Session 2 *Mathematical Biology II,* **P4703**

Chaired by Anita LAYTON

P4703 10.30–11.00

DEZHE Z. JIN
The statistical and neural network models of birdsong syntax (abstract, page 55)

P4703 11.00–11.30

DOUGLAS ZHOU
Modeling nonlinear dendritic integration using integrate-and-fire neuronal frameworks (abstract, page 91)

P4703 11.30–12.00

DANIEL B FORGER
A mechanism for robust daily timekeeping (abstract, page 50)

P4703 12.00–12.30

DAVID CAI
Causality analysis of neuronal network dynamics (abstract, page 42)

Parallel Session 3 *Analysis and Applications,* **P4704**

Chaired by Dan DAI

P4704 10.30–10.50

KIM TUAN VU
Inverse heat equation (abstract, page 79)

P4704 10.50–11.10

TOMMI SOTTINEN
Black–Scholes prices and hedges for financial derivatives in non-Gaussian non-martingale models (abstract, page 75)

P4704 11.10–11.30

DEJUN XIE
Mathematical modeling and analysis of mortgages (abstract, page 84)

P4704 11.30–11.50

WEN-MING HE* AND JUN-ZHI CUI
A note on multicsale theory (abstract, page 52)

P4704 11.50–12.10

MINVYDAS RAGULSKIS
The Hankel rank of a sequence for algebraic extrapolation of short time series (abstract, page 70)

P4704 12.10–12.30

Y. C. LIN
Some properties for generalized vector equilibrium problems (abstract, page 60)

12.30–14.00 *Lunch*

Plenary Talk **LT-18** 14.00–15.00 *Chaired by Chi-Wang SHU*

LLOYD N. TREFETHEN
How Chebfun solves ODEs and eigenvalue problems (abstract, page 77)

LT-18 15.00–15.30 Coffee Break

Parallel Session 1 *Computational Fluid Dynamics II,* **P4701**

Chaired by Jie SHEN

P4701 15.30–16.00

WEIQING REN
Boundary conditions for the moving contact line problem (abstract, page 71)

P4701 16.00–16.30

XIAO-PING WANG
An efficient adaptive method for the phase field simulation of moving contact line problem (abstract, page 81)

Parallel Session 2 *Computational Wave Propagation I,* **P4703**

Chaired by Xavier ANTOINE

P4703 15.30–16.00

S. ARRIDGE, T. BETCKE*, J. PHILLIS, M. SSCHWEIGER, AND W. ŚMIGAJ
BEM++ - A fast boundary element library (abstract, page 39)

P4703 16.00–16.30

C. GEUZAINE
A quasi-optimal non-overlapping domain decomposition algorithm for the Helmholtz equation (abstract, page 51)

P4703 16.30–17.00

MANFRED HAMMER
Guided wave interaction in photonic integrated circuits (abstract, page 51)

P4703 17.00–17.30

ERIC CHUNG
Staggered discontinuous Galerkin methods for the Maxwell's equations (abstract, page 47)

Parallel Session 3 *Numerical Methods I,* **P4704**

Chaired by Amiya PANI

P4704 15.30–15.50

JIAN DENG*, YAU SHU WONG, AND CRISTINA ANTON
Symplectic numerical schemes for stochastic Hamiltonian equations (abstract, page 47)

P4704 15.50–16.10

BIHONG CHEN
Use elementary column operations to calculate the basis of the null space of a matrix (abstract, page 44)

P4704 16.10–16.30

ZHIMING GAO* AND JIMING WU
A linearity preserving cell-centered scheme for the heterogeneous and anisotropic diffusion equations on general meshes (abstract, page 50)

P4704 16.30–16.50

CHIH-WEN CHANG
The new shooting method for solving nonlinear backward heat conduction problems (abstract, page 43)

18.00–21.00 Conference Banquet*

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)
*Conference Banquet:
Staff Lounge, City Top Restaurant, 9/F, Amenities Building

Thursday, 31 May 2012

LT-18 08.45–09.00 Registration

Plenary Talk **LT-18** 09.00–10.00 *Chaired by Gang BAO*

BJORN ENGQUIST
Simulation of multiscale dynamical systems (abstract, page 49)

LT-18 10.00–10.30 Coffee Break

Parallel Session 1 *Numerical Linear Algebra II,* **P4701**

Chaired by Xiao-Wen CHANG

P4701 10.30–11.00

ZHONGXIAO JIA
The shift-invert residual Arnoldi method and the Jacobi–Davidson method: theory and algorithms (abstract, page 55)

P4701 11.00–11.30

KARL MEERBERGEN
A rational Krylov method for a class of non-linear eigenvalue problems (abstract, page 64)

P4701 11.30–12.00

JIANLIN XIA
Randomized sparse direct solvers and applications (abstract, page 83)

Parallel Session 2 *Inverse Problems I,* **P4703**

Chaired by Bo ZHANG

P4703 10.30–11.00

JIN CHENG
Reconstruction of the Stefan-Boltzmann radiation coefficients in the heat transfer process (abstract, page 45)

P4703 11.00–11.30

PEIJUN LI
Generalized Foldy–Lax formulation (abstract, page 59)

P4703 11.30–12.00

HONGYU LIU
Near-cloak in acoustic scattering (abstract, page 61)

P4703 12.00–12.30

JIGUANG SUN
An eigenvalue method using multiple frequency data (abstract, page 76)

Parallel Session 3 *Mathematical Modeling II,* **P4704**

Chaired by Daihai HE

P4704 10.30–10.50

BUYANG LI
Heat and moisture transport in fibrous porous media with condensation/evaporation and fiber absorption (abstract, page 58)

P4704 10.50–11.10

LAURENT MERTZ
A stochastic variational inequality and applications to random vibrations and mechanical structures. (abstract, page 64)

P4704 11.10–11.30

CHIEN-HAO TSENG*, CHIA-CHEN KUO, CHUAN-LIN LAI, FANG-AN KUO, AND CHIH-WEN CHANG
Parallel computing for pilot-scale field of CO_2 geologic storage in taiwan (abstract, page 78)

P4704 11.30–11.50

DMITRY TERESHKO
Flow control problems for heat convection model (abstract, page 77)

P4704 11.50–12.10

DILIP KUMAR JAISWAL*, ATUL KUMAR, AND R. R. YADAV
Analytical solutions of temporally dependent dispersion for uniform and varying pulse type input source in one-dimensional semi-infinite porous media (abstract, page 54)

P4704 12.10–12.30

ATUL KUMAR*, DILIP KUMAR JAISWAL, AND NAVEEN KUMAR
One - dimensional solute dispersion along unsteady flow through heterogeneous medium: dispersion being proportional to square of velocity (abstract, page 56)

12.30–14.00 *Lunch*

Plenary Talk **LT-18** 14.00–15.00 *Chaired by David CAI*

PHILIP K. MAINI
Modelling aspects of tumour growth (abstract, page 63)

LT-18 15.00–15.30 Coffee Break

Parallel Session 1 *Numerical Linear Algebra III,* **P4701**

Chaired by Eric King-wah CHU

P4701 15.30–16.00

JUNGONG XUE*, QIANG YE
Computing exponentials of essentially non-negative matrices entrywise to high relative accuracy (abstract, page 87)

P4701 16.00–16.30

ZHENYUE ZHANG* AND KEKE ZHAO
Low rank matrix approximation with graph regularization (abstract, page 91)

P4701 16.30–17.00

QIANG YE
Computing eigenvalues of symmetric diagonally dominant matrices accurately with applications to differential operators (abstract, page 88)

Parallel Session 2 *Computational Wave Propagation II,* **P4703**

Chaired by Timo BETCKE

P4703 15.30–16.00

IGOR TSUKERMAN
Trefftz difference schemes and non-asymptotic Trefftz-Whitney homogenization (abstract, page 79)

P4703 16.00–16.30

SHINGYU LEUNG
Fbi-transform-based Eulerian Gaussian beams for the Schrödinger equation (abstract, page 58)

P4703 16.30–17.00

JINJIE LIU*, MOYSEY BRIO, AND JEROME V. MOLONEY
FDTD Techniques on overlapping cells and moving meshes (abstract, page 62)

P4703 17.00–17.30

XAVIER ANTOINE*, CHRISTOPHE GEUZAINE AND IBRAHIM ZANGRÉ
High-order shifted Laplace preconditioners for wave equations (abstract, page 38)

Parallel Session 3 *Numerical Methods II,* **P4704**

Chaired by Dongwoo SHEEN

P4704 15.30–15.50

WAI SUN DON AND RAFAEL BORGES*
Study of p and ε on the convergence properties of WENO-Z scheme (abstract, page 40)

P4704 15.50–16.10

ANTTI RASILA
Computation and applications of conformal modulus (abstract, page 70)

P4704 16.10–16.30

HYUN GEUN LEE* AND JUNSEOK KIM
A practical unconditionally gradient stable scheme for the N-component Cahn–Hilliard system (abstract, page 57)

P4704 16.30–16.50

HUA ZOU* AND HUA LI
A novel meshless method for solving integral equations (abstract, page 92)

P4704 16.50–17.10

PANKAJ BISWAS
Least-squares spectral element methods for parabolic problems using parallel computers (abstract, page 39)

P4704 17.10–17.30

WULAN, LI
Spectral methods for solving a fourth-order partial integro-differential equation with a weakly singular kernel (abstract, page 60)

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

Friday, 1 June 2012

Plenary Talk **LT-18** 09.00–10.00 *Chaired by Jun ZHOU*

GANG BAO
Direct and inverse modeling of near-field and nano-optics (abstract, page 39)

Parallel Session 1 *Numerical Analysis II,* **P4701**

Chaired by Eun Jae PARK

P4701 10.30–11.00

DONGWOO SHEEN
Recent progresses on quadrilateral nonconforming element methods (abstract, page 72)

P4701 11.00–11.30

AMIYA KUMAR PANI
Oldroyd model of viscoelastic fluids: some theoretical and computational issues (abstract, page 67)

P4701 11.30–12.00

DA XU
Uniform l^1 behavior for the numerical solutions of Volterra equations (abstract, page 85)

P4701 12.00–12.30

GRAEME FAIRWEATHER* AND ANDREAS KARAGEORGHIS
Compact optimal spline collocation methods for convection-diffusion problems (abstract, page 49)

Parallel Session 2 *Inverse Problems II,* **P4703**

Chaired by Jun ZOU

P4704 10.30–11.00

JIJUN LIU
Scattering and inverse scattering problems for acoustic waves by an obstacle with impedance boundary (abstract, page 61)

P4704 11.00–11.30

FUMING MA*, TIAN LUAN, ENXI ZHENG, AND MINGHUI LIU
Numerical computation for scattering problems of near field by using of the ultra weak variational formulation (abstract, page 63)

P4704 11.30–12.00

FAOUZI TRIKI
Imaging models based on surface plasmon resonances data (abstract, page 78)

P4704 12.00–12.30

KIHYUN YUN
Estimates for the scattering from an EM cavity (abstract, page 89)

12.30–14.00 *Lunch*

Plenary Talk **LT-18** 14.00–15.00 *Chaired by Jonathan WYLIE*

ALAN NEWELL
Pattern quarks and leptons (abstract, page 66)

LT-18 15.00–15.30 Coffee Break

Parallel Session 1 *Fluid Dynamics,* **P4701**

Chaired by Qiang ZHANG

P4701 15.30–16.00

MICHAEL K.H. CHAN*, KEKE ZHANG, XINHAO LIAO, AND JUN ZOU
Fluid motion in a triaxial ellipsoidal cavity driven by libration (abstract, page 42)

P4701 16.00–16.30

YUHUI DENG*, JONATHAN J. WYLIE, AND QIANG ZHANG
Instabilities of drag-induced particle segregation (abstract, page 48)

P4701 16.30–17.00

JONATHAN WYLIE
Asymptotic analysis of a viscous drop falling under gravity (abstract, page 83)

Parallel Session 2 *Inverse Problems III,* **P4703**

Chaired by Jin CHENG

P4704 15.30–16.00

JENN-NAN WANG
Inverse problems for elasticity, thin plate, and shallow shell equations by boundary measurements (abstract, page 81)

P4704 16.00–16.30

JIAQING YANG, BO ZHANG*, AND HAIWEN ZHANG
The factorization method for reconstructing a penetrable obstacle with unknown buried objects (abstract, page 89)

P4704 16.30–17.00

HAIJUN WU* AND LINGXUE ZHU
Pre-asymptotic error analysis of CIP-FEM and FEM for Helmholtz equation with high wave number (abstract, page 83)

P4704 17.00–17.30

JUN ZOU
Some direct and indirect sampling methods for inverse obstacle / medium scattering problems (abstract, page 92)

Location:
LT-18: Purple Zone, Level 4, Academic 1 (AC1)
Classroom: P4701, P4703, P4704, Purple Zone, Level 4, Academic 1 (AC1)

ABSTRACTS OF TALKS

High-order shifted Laplace preconditioners for wave equations

XAVIER ANTOINE*, CHRISTOPHE GEUZAINE AND IBRAHIM ZANGRÉ
University of Lorraine, France
Email: Xavier.Antoine@iecn.u-nancy.fr

Shifted Laplace preconditioners techniques have been introduced by Erlangga, Vuik and Ooterlee (Applied Numerical Mathematics, 2004) for solving PDEs problems related to wave-like equations. The aim of this talk is to propose a generalization of shifted Laplace preconditioning methods by using operator representation combined with complex Padé approximants. We will show that the resulting high-order shifted Laplace preconditioners are highly efficient and robust for two- and three-dimensional scattering problems that exhibit complex geometrical features (e.g. resonant structures). Furthermore, the convergence is proved to be weakly frequency dependent.

Stochastic Eulerian Lagrangian methods for microscopic hydrodynamics and the study of fluid-structure interactions subject to thermal fluctuations

PAUL J. ATZBERGER
University of California (Santa Barbara), USA
Email: atzberg@math.ucsb.edu

Many problems in fluid mechanics involve the interaction of hydrodynamic flow with elastic structures. In soft materials where the energetics of microstructure interactions are comparable to thermal energy, computational simulations must also incorporate spontaneous thermal fluctuations. For traditional continuum mechanics descriptions this presents a variety of challenges both in formulating appropriate stochastic physical models and in developing efficient computational methods. In the context of fluid-structure interactions, additional challenges arise from the often subtle interplay between elastic mechanics, hydrodynamic coupling, and thermal fluctuations. In this talk, we present a set of new approaches based on a mixed Eulerian and Lagrangian description that incorporates in the description of fluid-structure interactions the role of thermal fluctuations. For the fluctuating hydrodynamics based description we address central mathematical, physical, and computational issues. We then develop numerical methods for the approximation of the resulting stochastic partial differential equations and their temporal integration. To illustrate our approach in practice, we also discuss results for specific applications including studies of polymeric fluids, vesicles, gels, and lipid bilayer membranes.

Direct and inverse modeling of near-field and nano-optics

GANG BAO
Zhejiang University, China; Michigan State University, USA
Email: bao@math.msu.edu

This talk is concerned with the following two classes of problems that arise in the modeling and simulations of near-field and nano optics: (1) Inverse scattering via near-field imaging. The goal is to determine fine features of the scatterer by near-field boundary measurements of the fields and to achieve super-resolution or to break the diffraction limit. The speaker will analyze the significant role of the evanescent fields and present recent results on numerical reconstruction of multiscale profiles. Issues on illposedness and nonlinearity of the inverse problems will be addressed. (2) Multiscale and multiphysics modeling of optical interactions of light and nano materials/structures. A semiclassical model based on the coupling of Maxwell's and Schrodinger equations will be investigated. Computationally, a novel approach by combining Maxwell's equations and time dependent density function theory will be proposed and discussed.

The model problems have diverse applications particularly in nano and bio science. The speaker will highlight related ongoing and future research projects.

BEM++ - A fast boundary element library

S. ARRIDGE, T. BETCKE*, J. PHILLIS, M. SSCHWEIGER, AND W. ŚMIGAJ
University College London, UK
Email: t.betcke@ucl.ac.uk

BEM++ is a project to develop an open-source Galerkin boundary element library for the solutions of problems in electrostatics, acoustics, computational electromagnetics and elasticity. The library is fully built in C++ and highly extensible. The basic grid management builds around the DUNE project. The core integrators are provided as CPU and GPU versions. H-Matrix acceleration is provided via interfaces to the AHMED library, and FMM routines are in development. A linear algebra framework is implemented via interfaces to Trilinos. For ease of use Python interfaces are being developed and Matlab interfaces are in planning.

In this talk we present the current state of the project, give examples and discuss future directions of the development.

Least-squares spectral element methods for parabolic problems using parallel computers

PANKAJ BISWAS
Birla Institute of Technology & Science, India
Email: pankaj.biswas2002@gmail.com

This paper studies a space-time coupled least-squares spectral element method for parabolic initial boundary value problems using parallel computers. The space domain is divided into

a number of shape regular quadrilaterals of size h and the time step k is proportional to h^2. Each quadrilateral is mapped onto the unit square and the time interval $(nk,(n+1)k)$ is mapped onto the interval $I=(0,1)$ by a set of smooth maps. At each time step the solution is defined to be a polynomial of degree p in each of the space variables and of degree q in the time variable. The spectral element functions considered are non-conforming.
We do not need to consider C^0 element expansions at the inter element boundaries and consequently it is unnecessary to express the equation as an equivalent set of first-order equations by introducing additional independent variables. We minimize at each time step a functional which is the sum of the squares of the residuals in the partial differential equation, the initial condition and boundary condition in different Sobolev norms and a term which measures the jump in the function and its derivatives across inter-element boundaries in certain Sobolev norms. A preconditioner can be defined which allows the problem to decouple. The condition number of the preconditioned system is $O(\frac{(ln(p))^4}{h^2})$. The normal equations obtained from the least-squares formulation can be solved by preconditioned conjugate gradient method (PCGM) in matrix-free form.
In the p-version of the method q is proportional to p^2 and p tends to infinity. If the solution belongs to a certain Gevrey space then for the p-version of the method the error between the exact solution and the approximate solution decays exponentially in p. We choose $p=2q+1$ and let h tend to zero for the h-version of the method. In the h-version the error is $O(h^{(2q-1)})$. Moreover, the number of iterations required to obtain the approximate solution using PCGM is $O(\frac{(ln(p))^2}{h})$ per time step. The computational results confirm the estimates that have been obtained.

Study of p and ε on the convergence properties of WENO-Z scheme

WAI SUN DON AND RAFAEL BORGES*
Hong Kong Baptist University, Hong Kong
*Universidade Federal do Rio de Janeiro, Brazil
Email: thalasyus@gmail.com

It is known that solutions of systems of hyperbolic conservation laws equations may develop discontinuities, such as shock waves or contact discontinuities, even with smooth initial data. This feature of hyperbolic PDE poses both theoretical and numerical challenges. High order conservative Weighted Essentially Non-Oscillatory (WENO) finite difference schemes are a popular choice for solving hyperbolic conservation laws problems, for they are able to resolve the small scales structures of the flow with high resolution while capturing shocks in an essentially non-oscillatory manner. In the WENO reconstruction step, nonlinear weights ω_k are employed for distinguishing the smooth parts of the solution from the discontinuities via smoothness indicators β_k. There are several variants of nonlinear weight formulations, such as the classical ones derived by Jiang and Shu, the mapped weights of Henrick et al. and the WENO-Z weights derived by Borges et al. All these formulations share two important, free parameters in common: the power p, which controls the dissipation of the scheme, and the ε, which was introduced to avoid a division by zero in the denominator of the nonlinear weights ω_k. However, the value of ε also plays a significant, collateral role in the behavior of the order of accuracy of WENO schemes, specially in the presence of critical points. It has been shown that the ε used in the classical WENO scheme by Jiang and Shu has to be chosen as $\varepsilon = O(\Delta x^2)$, in order to guarantee the formal order of the accuracy of the scheme. Furthermore, it must always be chosen that way, regardless of the order of the scheme. This is a relatively restrictive condition, as a smaller ε is desirable for better capturing an essentially non-oscillatory shock. The general belief is that ε must be of $O(\Delta x^2)$ for any order of WENO scheme in order to attain the formal order of accuracy. We will show that the formal order of accuracy is assured, even in the presence of critical points, by choosing $\varepsilon = O(\Delta x^q)$, with $q > 2$, using the improved WENO-Z scheme of any order. This is a desirable feature, for a smaller ε allows better shock capturing as it does not dominate over the size of the smoothness indicators β_k. Moreover, WENO schemes tend to have a reduced rate of convergence when Δx is relatively large. We will show that one can recover the formal order of accuracy for large Δx by adaptively choosing ε. We will present the analysis and numerical experiments to validate our claims.

The control problems for time–harmonic Maxwell and Helmholtz equations

G. ALEKSEEV AND R. BRIZITSKII*
Far Eastern Federal University, Russia
*Institute of Appled Mathematics FEB RAS, Russia
Email: mlnwizard@mail.ru

Control problems for time–harmonic Maxwell and Helmholtz equations are considered. These problems arise when solving inverse problems for Maxwell and Helmholtz equations using nonlinear optimization techniques. The first control problem is formulated for time–harmonic Maxwell equations, considered under mixed boundary conditions in the case when the tangential component of electric field is given on one part of the boundary and the impedance boundary condition is imposed on another its part. This problem consists of minimization of certain cost functionals depending on the state (electric field) and unknown functions (controls). The role of controls in control problem under study is played by boundary functions entering into the impedance boundary condition and by density of electric current. Quadratic tracking–type functionals for the electric or magnetic field play the role of cost functionals. Solvability of both the initial mixed boundary value problem and control problems for Maxwell equations is proved. The optimality systems describing the first–order necessary optimality conditions are derived. Based on the optimality system analysis, a special inequality for the difference of solutions to the original and perturbed control problems is deduced. Using this inequality, sufficient conditions to the data ensuring the local uniqueness and stability of solutions of concrete control problems with respect to certain perturbations both cost functional and some functions entering into original boundary problem are established.

The second control problem is formulated for generalized Helmholtz equation describing propagation of acoustics waves in inhomogeneous anisotropic medium. This problem is connected with constructing nonscattering shells filled with anisotropic fluid. The control problem consists of minimization of a suitable cost functional depending on the state (acoustic pressure) and unknown functions (controls). The optimality system for the general control problem is derived, the sufficient conditions for data which provide a local stability and uniqueness of control problems under study for concrete tracking-type cost functionals are established.

Causality analysis of neuronal network dynamics

DAVID CAI
Shanghai Jiao Tong University, China; New York University, USA
Email: `cai@cims.nyu.edu`

How to characterize information flows and causality within neuronal network dynamics is an important and challenging scientific question. For linear stochastic systems, Granger Causality analysis is an effective tool to address the issue of causal influence. Here we demonstrate that Granger Causality can be successfully extended to analyze network connections of nonlinear neuronal network dynamics of integrate-and-fire type. We address why Granger Causality can be used to analyze this type of nonlinear network systems and reveal the underlying mechanism for this effective linearization of nonlinear neuronal network dynamics.

Fluid motion in a triaxial ellipsoidal cavity driven by libration

MICHAEL K.H. CHAN*, KEKE ZHANG, XINHAO LIAO AND JUN ZOU
The University of Hong Kong, Hong Kong
Email: `mkhchan@hkucc.hku.hk`

Deformed by tidal forces and rotational effects, the cavity of a planetary fluid core is usually in the shape of non-spherical geometry. Gravitational interaction between a planet and its parent star or moon exerts a torque on the planet and forces its latitudinal libration which drives fluid motion in non-spherical planetary cores via viscous and topographic coupling between the planetary mantle and fluid core. We shall present an asymptotic theory – a mathematical solution of the Navior-Stokes solution in spheroidal geometry with small viscosity – describing the fluid motion driven by latitudinal libration. We shall also present an efficient finite element method for simulating nonlinear flows in latitudinally librating, triaxial ellipsoidal cavities with stability properties and error estimates of the time-dependent finite element solution.

Image segmentation by convex approximation of the Mumford-Shan model

XIAOHAO CAI, RAYMOND CHAN*, AND TIEYONG ZENG
The Chinese University of Hong Kong, Hong Kong
Email: `rchan@math.cuhk.edu.hk`

The Mumford-Shah model is one of the most important image segmentation models, and has been studied extensively in the last twenty years. We propose a convex segmentation model based on the Mumford-Shah model. Our model can be seen as finding a smooth approximation g to the piecewise smooth solution of the Mumford-Shah model. Once g is obtained, the two-phase or multiphase segmentation is done by thresholding g. The thresholds can be given by the users to reveal specific features in the image or they can be obtained automatically using a K-means method. Because of the convexity of the model, g can be solved efficiently by

techniques like the split-Bregman algorithm or the Chambolle-Pock method. We prove that our model is convergent and the solution g is always unique. In our method, there is no need to specify the number of segments K ($K \geq 2$) before finding g. We can obtain any K-phase segmentations by choosing $(K-1)$ thresholds after g is found; and there is no need to recompute g if the thresholds are changed. Experimental results show that our method performs better than many standard 2-phase or multi-phase segmentation methods for very general images, including anti-mass, tubular, noisy, and blurry images.

The new shooting method for solving nonlinear backward heat conduction problems

CHIH-WEN CHANG
National Center for High-Performance Computing, Taiwan
Email: 0903040@nchc.narl.org.tw

In this study, the nonlinear backward heat conduction problem (BHCP) is investigated numerically. The BHCP is well-known as severely ill-posed because the solution does not continuously depend on the given data. First, this ill-posed problem is analyzed by contemplating the semi-discretization numerical approaches and then, the resulting ordinary differential equations at the discretized spaces are numerically integrated towards the time direction by utilizing the new shooting method to search the unknown initial conditions. The significant point is on the basis of the construction of a one-step Lie group element G(T) and the formation of a generalized mid-point Lie group element G(r). After that, by imposing G(T) = G(r) we can seek the missing initial conditions through a minimum discrepancy of the target in terms of the weighting factor Several numerical instances with noisy data are discussed.

Two floating point LLL lattice reduction algorithms

XIAO-WEN CHANG
McGill University, Canada
Email: chang@cs.mcgill.ca

The Lenstra-Lenstra-Lovasz (LLL) lattice reduction has many applications, including digital communications. It can greatly improve the speed of the sphere decoding (SD) algorithms for solving an integer least squares (ILS) problem and the performance of the Babai integer point, a suboptimal solution to the ILS problem. Recently Ling and Howgrave-Graham proposed the so-called effective LLL (ELLL) reduction algorithm. It has less computational complexity than the original LLL algorithm in terms of floating point operations, while it has the same effect on the performance of the Babai integer point as the latter. In this talk we first present a floating point partial LLL (PLLL) reduction algorithm. PLLL avoids the numerical stability problem with ELLL, which may result in very poor performance of the Babai integer point. Furthermore, numerical simulations indicated that it is faster than ELLL. Based on PLLL, we then present a floating point block LLL (BLLL) reduction algorithm, which is rich in matrix-matrix multiplications. Experimental results will be given to show performance improvement.

Use elementary column operations to calculate the basis of the null space of a matrix

BIHONG CHEN
ShenZhen University, China
Email: cbhmath@hotmail.com

This paper gives and proofs a theorem, for any matrix A, do elementary column operations, change it to a matrix which is partitioned to two blocks which left one is column full rank and right one is zero matrix. That is, use a invertible matrix P to let AP=(B,O), O is zero matrix with n-r columns, r and n is rank and column number of A, so the P's right n-r columns is just the basis of the null space of the matrix A. On the basis of the theorem, lots of problems of linear algebra can be resolved and lots of theorems can be proofed by elementary column operations. Perhaps the textbooks used in universities will have a lot of change with the result of the paper. This result is first found by author in 2010.12.8 in http://www.paper.edu.cn/index.php/default/releasepaper/content/201012-232, but is not formal published.

Dynamics for a two-dimensional Hindmarsh-Rose type model with four parameters

SHYAN-SHIOU CHEN* AND CHANG-YUAN CHENG
*National Taiwan Normal University, Taiwan
National PingTung University of Education, Taiwan
Email: sschen@ntnu.edu.tw

In this study, we provide a global picture of the bifurcation scenario of a two-dimensional Hindmarsh-Rose type model with four parameters. We present all of the possible classifications based on the following results: first, the number and stability of the equilibrium are analyzed in detail with a table built to show not only how to change the stability of the equilibrium but also which two equilibria collapse through the saddle-node bifurcation; secondly, sufficient conditions for an Andronov-Hopf bifurcation and a saddle-node bifurcation are mathematically confirmed; and finally, we provide sufficient conditions for a Bogdanov-Takens (BT) bifurcation and a Bautin bifurcation. Several numerical simulations for these conditions are presented. In particular, two types of bistable behaviors are numerically shown: one is from the Bautin bifurcation, and the other is from the BT bifurcation. We also notice that all of the bifurcations curves in the domain of the remaining three parameters are almost the same when the time scale is sufficiently large. Additionally, to show the existence of a limit cycle, the existence of a trapping region is demonstrated. These results provide us a diversity of behaviors for the model. The results in the paper should be helpful when choosing suitable parameters for fitting experimental observations.

Reconstruction of the Stefan-Boltzmann radiation coefficients in the heat transfer process

JIN CHENG
Fudan University, China
Email: jcheng@fudan.edu.cn

In this talk, we will present our recent results for an inverse problem on the determination of boundary coefficients within the framework of Stefan-Boltzmann radiation conditions for the heat transfer process. This study is motivated by our joint research on the quality control in the metal sheet production with a steel company. The suitable mathematical model is introduced. Based on the theoretical analysis for the problem, we propose a fast and effective reconstruction method for solving the inverse problem. Numerical simulation shows that our reconstruction method is stable and effective.

Mathematical modelling of tumor growth

FION WK CHEUNG* AND DOUGLAS KS NG
*Queen Elizabeth Hospital, Hong Kong
City University of Hong Kong, Hong Kong
Email: fioncheung210@yahoo.com.hk

Cancer is the second most killer in the world today. Models of cancer growth have been the subject of research in the areas of Mathematical Modelling, Mathematical Biology, etc. In this talk, we will describe some elements on two mathematical models formulation of tumor growth. The models formulation were based on some biological assumptions, such as i) the rate of change of tumor size = rate of tumor growth − rate of tumor degradation; ii) tumor cell numbers were proliferating within a spheroid model. The models have been empirically tested and compared with the real data of nasopharyngeal carcinoma (NPC) patient. In addition, tumor control probability (TCP) and normal tissue complication probability (NTCP) models were adopted to estimate the radiological response.

Implicit sampling, with applications to filtering and data assimilation

ALEXANDRE J. CHORIN
University of California (Berkeley), USA
Email: chorin@math.berkeley.edu

In many problems of computational sciene it is necessary to sample a given probability density (pdf), i.e., use a computer to construct a sequence of independent random vectors $x_i, i = 1,2,\dots,$ whose histogram converges to the given pdf. This can be difficult because the sample space is typically huge, and more important, because the portion of the space where the density is significant can be very small, so that one may miss it by an ill-designed sampling scheme. Indeed, Markov-chain Monte Carlo (MCMC), the most widely used sampling scheme, can be thought of as a search algorithm, where one starts at an arbitrary point and one advances step-by-step towards the high probability region of the space. This can be expensive, in particular because one is typically interested in independent samples, while the chain has a memory. I will present an alternative, in which samples are found by solving an algebraic equation with a random input rather than by following a chain; each sample is independent of the previous samples. We explain the construction in the context of numerical integration, and then apply it to filtering and data assimilation, where success requires efficient sampling.

(Joint work with M. Morzfeld and X. Tu).

Fast sweeping methods for steady state problems for hyperbolic conservation laws

CHING-SHAN CHOU
Ohio State University, USA
Email: chou@math.ohio-state.edu

In this talk, I will discuss several simple fast sweeping methods to approximate the steady state solutions of hyperbolic conservation laws. The original fast sweeping methods were developed for stationary Hamilton-Jacobi equations. The methods relies on numerical Hamiltonian, Gauss-Seidel type nonlinear iterative method, and a finite number of sweeping directions to compute the stationary viscosity solution efficiently. We extend the fast sweeping methods to solve hyperbolic conservation laws with source terms. By incorporating the numerical flux, we developed efficient methods which can capture correct stationary viscosity solutions even when discontinuities appear. Extensive numerical examples in both scalar and system of equations in one-, and two-dimensions illustrate the efficiency and accuracy of the new approach.

Structured solution of large-scale nonlinear matrix equations

ERIC KING-WAH CHU
Monash University, Australia
Email: eric.chu@sci.monash.edu.au

Nonlinear matrix equations, such as $X + BX^{-1}A + C = 0$ and $AX + XD - XCX + B = 0$, arise in many applications, such as vibration analysis, optimal control, queueing systems, nano research and economic dynamics. The exploitation of specific symmetry and structures in these equations is vital in their numerical solution, especially for large-scale problems. Much have been achieved recently, using Newton's iteration, cyclic reduction, doubling and other methods. The talk will exhibit some of these advances and achievements, especially for structure-preserving doubling algorithms.

Staggered discontinuous Galerkin methods for the Maxwell's equations

ERIC CHUNG
The Chinese University of Hong Kong, Hong Kong
Email: `tschung@math.cuhk.edu.hk`

We will present a new staggered discontinuous Galerkin method for the Maxwell's equations. One distinctive feature of the method is that the discrete operators preserve the properties of the differential operators. Moreover, the numerical solution automatically satisfies a discrete divergence-free condition. Stability and optimal convergence of the method are analyzed. Numerical experiments for smooth and singular solutions are shown to verify the optimal order of convergence. Furthermore, numerical results for the corresponding eigenvalue problem show that our method is able to suppress spurious eigenvalues.

Minimizing communication

JAMES DEMMEL
University of California (Berkeley), USA
Email: `demmel@cs.berkeley.edu`

Algorithms have two kinds of costs: arithmetic and communication, by which we mean moving data either between levels of a memory hierarchy (in the sequential case) or between processors over a network (in the parallel case). Communication costs (measured in time or energy per operation) can already exceed arithmetic costs by orders of magnitude, and the gap is growing over time following technological trends. Thus our goal is to design algorithms that minimize communication. First, we show how to extend known communication lower bounds for $O(n^3)$ dense matrix multiplication to all direct linear algebra, i.e. for solving linear systems, least squares problems, eigenproblems and the SVD, for dense or sparse matrices, and for sequential or parallel machines. We also describe new algorithms that attain these lower bounds; some implementations attain large speed ups over conventional algorithms. Second, we show how to minimize communication in Krylov-subspace methods for solving sparse linear system and eigenproblems, and again demonstrate new algorithms with significant speedups. Finally, we indicate how some of these results extend to even more general classes of algorithms.

Symplectic numerical schemes for stochastic Hamiltonian equations

JIAN DENG*, YAU SHU WONG, AND CRISTINA ANTON
University of Alberta, Canada
Email: `jdeng@math.ualberta.ca`

We propose a new method to develop high order symplectic schemes for Hamiltonian stochastic differential equations. This approach is an non- trivial extension to the stochastic case of the

methods based on generating functions for deterministic Hamiltonian systems. We consider the stochastic differential equations in the sense of Stratanovich:

$$\begin{aligned} dP &= -\frac{\partial H^{(0)}(t,P,Q)}{\partial Q}dt - \sum_{r=1}^{m} \frac{\partial H^{(r)}(t,P,Q)}{\partial Q} \circ dw_t^r, \quad P(t_0) = p \\ dQ &= \frac{\partial H^{(0)}(t,P,Q)}{\partial P}dt + \sum_{r=1}^{m} \frac{\partial H^{(r)}(t,P,Q)}{\partial P} \circ dw_t^r, \quad Q(t_0) = q \end{aligned} \tag{1}$$

where P,Q,p,q are n-dimensional vectors with the components $P^i,Q^i,p^i,q^i, i = 1,\ldots,n$, and $w_t^r, r = 1,\ldots,n$ are independent standard Wiener Processes. The equations (1) represent a stochastic Hamiltonian system for which the stochastic flow $(p,q) \to (P,Q)$ is symplectic. We associate the following stochastic partial differential equation with the system (1):

$$dS_\omega^1 = H^{(0)}(P, q + \frac{\partial S_\omega^1}{\partial P})dt + \sum_{r=1}^{m} H^{(r)}(P, q + \frac{\partial S_\omega^1}{\partial P}) \circ dw_t^r \tag{2}$$

$(p,q) \to (P(t,\theta(t)\omega), Q(t,\theta(t)\omega))$ defined by $p = P + \frac{\partial S_\omega^1}{\partial q}(P,q), \quad Q = q + \frac{\partial S_\omega^1}{\partial P}(P,q)$ is the flow of (1). We use this relationship between the generating function S_ω^1 and the solutions of the system (1) to construct symplectic numerical schemes based on approximations of the solutions of the partial differential equation (2). By construction these schemes preserve the symplectic structure. We illustrate the excellent long term accuracy of the proposed schemes on several examples with additive and multiplicative noise.

Instabilities of drag-induced particle segregation

YUHUI DENG*, JONATHAN J. WYLIE, AND QIANG ZHANG
Harbin Institute of Technology Shenzhen Graduate School, China
Email: ivandengyh@gmail.com

We consider two different types of spherical particles with different radii but equal density are excited by collision with a vibrating boundary. Particles in the system experience both gravity and linear drag force. We show that particle segregation occurs and a "sandwich" layer formed by the large particles oscillates periodically. Furthermore, for a fixed ratio of drag force and gravity, the sandwiched layer oscillates at a constant frequency for varying energy input rates. Both the mean height and the amplitude of oscillation are directly proportional to the energy input rate. We develop a theoretical model that gives numerical solutions for the frequency and amplitude of the oscillation and the mean height of the sandwiched layer. Our model allows us to qualitatively analyze a number of interesting phenomena for this system.

Preconditioning techniques for the electromagnetic scattering from a large cavity

KUI DU
Xiamen University, China
Email: kuidu@xmu.edu.cn

The electromagnetic scattering from a two-dimensional cavity is described by the Helmholtz equation with a nonlocal boundary condition on the aperture of the cavity and Dirichlet (or Neumann) boundary conditions on the walls of the cavity. In this talk, we introduce several preconditioning techniques developed in recent years for the electromagnetic cavity problem. In addition, for the cavity with a small portion of non-layered media, we propose a sparse preconditioned conjugate orthogonal conjugate gradient solver. Numerical results are reported to demonstrate the efficiency of the preconditioning techniques and the sparse solver.

Simulation of multiscale dynamical systems

BJORN ENGQUIST
The University of Texas at Austin, USA
Email: engquist@math.utexas.edu

The heterogeneous multiscale method is a framework that can be used to design and analyze numerical methods for stiff ordinary and partial differential equations with oscillatory solutions. We will discuss the difficulty of finding macro-scale variables and also compare the heterogeneous multiscale method with related techniques. Applications to molecular dynamics will be considered.

Compact optimal spline collocation methods for convection-diffusion problems

GRAEME FAIRWEATHER* AND ANDREAS KARAGEORGHIS
*American Mathematical Society, USA
University of Cyprus, Cyprus
Email: gxf@ams.org

Methods involving smoothest spline collocation have been used frequently in the solution of various ordinary and partial differential equations. Often overlooked is the fact that, in their basic form, such methods yield suboptimal approximations. In this talk, we describe new modified spline collocation methods based on quadratic and cubic splines for the solution of convection-diffusion problems in one space variable. The approximate solutions are not only of optimal global accuracy but also exhibit superconvergence phenomena. Moreover, the methods are compact in that they require the solution of only tridiagonal systems of linear equations. We present results of numerical experiments to demonstrate properties of the new methods.

A mechanism for robust daily timekeeping

DANIEL B FORGER
University of Michigan, USA
Email: forger@umich.edu

Circadian clocks persist with a constant period (24-hour) even after a significant change of the expression level of clock genes. To study the biochemical mechanisms of timekeeping, we develop the most accurate mathematical model of mammalian intracellular timekeeping, as well as a simplified model amenable to mathematical analysis. This modeling work raises interesting questions about existence and uniqueness of models given knowledge of their solutions. Although much is known about cellular circadian timekeeping, little is known about how these rhythms are sustained with a constant period. Here, we show with simulations and analysis how a universal motif of circadian timekeeping, where repressors bind activators rather than directly binding to DNA, can generate oscillations when activators and repressors are in stoichiometric balance. Furthermore, we find that an additional slow negative feedback loop keeps this stoichiometry in balance and maintains oscillations with a fixed period. These results explain why the network structure found naturally in circadian clocks can generate 24-hour oscillations in many conditions.

A linearity preserving cell-centered scheme for the heterogeneous and anisotropic diffusion equations on general meshes

ZHIMING GAO* AND JIMING WU
Institute of Applied Physics and Computational Mathematics, China
Email: dtgaozm@gmail.com

In this talk a finite volume scheme for the heterogeneous and anisotropic diffusion equations is proposed on general, possibly nonconforming meshes. This scheme has both cell-centered unknowns and vertex unknowns. The vertex unknowns are treated as intermediate ones and are expressed as a linear weighted combination of the surrounding cell-centered unknowns, which reduces the scheme to a completely cell-centered one. We propose two types of new explicit weights which allow arbitrary diffusion tensors, and are neither discontinuity dependent nor mesh topology dependent. Both the derivation of the scheme and that of new weights satisfy the linearity preserving criterion which requires that a discretization scheme should be exact on linear solutions. The resulting new scheme is called as the linearity preserving cell-centered scheme and the numerical results show that it maintain optimal convergence rates for the solution and flux on general polygonal distorted meshes in case that the diffusion tensor is taken to be anisotropic, at times heterogeneous, and/or discontinuous.

A quasi-optimal non-overlapping domain decomposition algorithm for the Helmholtz equation

C. GEUZAINE
University of Liège, Belgium
Email: cgeuzaine@ulg.ac.be

In this talk we will propose the construction and analysis of a new non-overlapping domain decomposition method for the wave equation in harmonic regime. The method is well-suited for high-performance computing of scattering problems, especially in the high-frequency regime, which is currently an important and challenging problem in numerical analysis. A key aspect of our approach is the construction of a efficient transmission operator between the subdomains, based on accurate local approximations of the exact Dirichlet-to-Neumann operator. We will compare our approach to the standard reference approaches and show on 2-D and 3-D examples that our method leads to a convergence rate that varies only slightly with frequency and mesh refinement. This is a major advantage compared to competing approaches, which makes the method an excellent candidate for large scale scattering simulations. We will also show that the implementation of the method is relatively easy in the context of standard finite element codes.

Joint work with X. Antoine, Y. Boubendir and B. Thierry.

Guided wave interaction in photonic integrated circuits

MANFRED HAMMER
University of Twente, The Netherlands
Email: m.hammer@ewi.utwente.nl

For already several decades a trend towards miniaturization of optical systems can be observed. Optical components with diverse functionalities are to be combined into single monolithic “chips”. The field is called integrated optics, a subdivision of photonics. Concrete design efforts as well as fundamental investigations rely heavily on computer simulations. Analytical solutions, even for linear problems, exist only for few, highly symmetric, exceptional cases. One resorts to rigorous numerical methods, which very often lead to schemes with unacceptably large computational effort. Hence there is substantial interest in simplifying models for certain classes of problems.

We will focus on a quite general variant of what is known as coupled mode theory. The propagation and interaction of guided optical waves is to be predicted. Starting point is a physically reasonable field template. Typically this consists of a few known, most relevant modes of the optical channels in the structure, superimposed with coefficient functions of the respective — in principle arbitrary — propagation coordinates. Also the resonant eigenfields of optical cavities can be included, multiplied by single unknowns. Discretization of the unknown functions into 1-D finite elements leads to an approximation of the optical field in terms of a linear superposition of structure-adapted, more or less localized modal elements. By means of a projection procedure of Galerkin type, or alternatively by variational restriction of a functional representation of the full 2-D/3-D vectorial first order Maxwell equations in the frequency domain (with transparent influx boundary conditions for inhomogeneous exterior), one can then reduce the problem to a small- to moderate-sized system of linear equations. A series of 2-D examples, including a crossing of dielectric waveguides, waveguide Bragg gratings, and circuits of micro-ring or -disk resonators, illustrate the performance of the approach.

Investigating the causes of the three waves of the 1918 influenza pandemic in England and Wales

DAIHAI HE*, JONATHAN DUSHOFF, TROY DAY, JUNLING MA, AND DAVID EARN
Hong Kong Polytechnic University, Hong Kong
Email: daihai.he@inet.polyu.edu.hk

Past influenza pandemics appear to be characterized by multiple waves of incidence but the mechanisms that account for this phenomenon remain unclear. We proposed a simple epidemic model in which we incorporate three factors that might contribute to the generation of multiple waves: (i) schools opening and closing, (ii) temperature changes during the outbreak, and (iii) changes in human behavior in response to the outbreak. We fitted this model to the reported influenza mortality data of the 1918 pandemic from 334 UK administrative units, and estimated the epidemiological parameters. We then use information criteria to identify which of the three factors provides the best explanation for the multiple waves seen in the data. Our results suggest that all three factors are important and that, taken together, a model with these factors can produce epidemiological dynamics that match the data well for reasonable parameter values.

A note on multicsale theory

WEN-MING HE* AND JUN-ZHI CUI
*Wenzhou University, China
Chinese Academy of Sciences, China
Email: he_wenming@yahoo.com.cn

In this paper, we shall discuss the multi-scale homogenization theory for second order elliptic problems with small periodic coefficients of the form $\frac{\partial}{\partial x_i}(a^{ij}(\frac{x}{\varepsilon})\frac{\partial u^\varepsilon(x)}{\partial x_j}) = f(x)$. Assume that $n = 2$ and $u^0 \in W^{1,\infty}(\Omega)$, we present an error estimate between the homogenization solution $u^0(x)$ and the exact solution $u^\varepsilon(x)$ on the Sobolev space $L^\infty(\Omega)$.

Optimization, adaptation, and initiation of biological transport networks

DAN HU
Shanghai Jiao Tong University, China
Email: hudan80@sjtu.edu.cn

Blood vessel systems and leaf venations are typical biological transport networks. The energy consumption for such a system to perform its biological functions is determined by the network structure. In the first part, I will talk about the optimized structure of the network, and show how the blood vessel system adapts itself to an optimized structure. Mathematical models are used to predict pruning vessels in the experiments of zebra fish. In the second part, I will discuss our recent discovery on modeling the initiation of transport networks. Simulation results are used to illustrate how a tree-like structure is obtained from a continuum adaptation equation set, and how loops can exist in our model. Possible further application of this model will also be discussed.

A simple boundary condition for terminating photonic crystal waveguides

ZHEN HU* AND YA YAN LU
*Hohai University, China
City University of Hong Kong, Hong Kong
Email: huzhen1230@gmail.com

A photonic crystals (PhC) is periodic structure with a period on the scale of the wavelength of light. Various devices have been proposed based on PhCs which often have PhC waveguides as the input and output ports. Numerical simulations for a PhC device require artificial boundary conditions to terminate the PhC waveguides. A rigorous boundary condition for terminating a PhC waveguide is available, but it is a nonlocal condition that connects the wave field at different points on a line or plane (for 2D or 3D structures, respectively) perpendicular to the waveguide axis. For 3D structures, this boundary condition becomes too expensive to use. We propose a simple boundary condition for terminating PhC waveguides.
Consider a semi-infinite PhC waveguide given in $x < x_0$. Let $\phi_l^+(x,y)e^{i\beta_l x}$ and $\phi_l^-(x,y)e^{-i\beta_l x}$, $1 \le l \le l_*$, be the incoming and outgoing propagating Bloch modes of the waveguide. If the line $x = x_0$ is sufficiently far away from the center of the device, the evanescent modes in the waveguide can be ignored, then the wave field in the waveguide can be approximated by $u \approx u^{(i)} + \sum_{l=1}^{l_*} b_l \phi_l^-(x,y)e^{-i\beta_l x}$. A local boundary condition can be derived by eliminating the unknown coefficients b_l. It is given as

$$u_0 + B_1 u_1 + \cdots + B_{l_*} u_{l_*} = u_0^{(i)} + B_1 u_1^{(i)} + \cdots + B_{l_*} u_{l_*}^{(i)},$$

where B_0, B_1, ... are some coefficients, $x_l = x_0 + la$, $u_l = u(x_l, y)$ and $u_l^{(i)} = u^{(i)}(x_l, y)$.

Analytical solutions of temporally dependent dispersion for uniform and varying pulse type input source in one-dimensional semi-infinite porous media

DILIP KUMAR JAISWAL*, ATUL KUMAR, AND R. R. YADAV
Lucknow University, India
Email: dilip3jais@gmail.com

In the present study, analytical solutions of advection dispersion equation (ADE) are obtained for uniform and varying pulse type input source by using Laplace transform technique. Temporally dependent dispersion is considered along uniform flow. The domain is one-dimensional homogeneous semi-infinite. Due to many reason (i.e., human activities and climate change caused by pollution), the domain of medium is not solute free. It is combination of (i) ratio of zero order production and first decay which are inversely propor-tional to dispersion coefficient and (ii) exponentially increasing function of position variable. The variable transport equation (ADE) is reduced into constant coefficients by introducing new space and time variables. Illustrations are given with different graphs.

Mathematical analysis of cell growth within tissue-engineering scaffolds

DARAE JEONG*, ANA YUN, AND JUNSEOK KIM
Korea University, Korea
Email: tinayoyo@korea.ac.kr

A scaffold is a three-dimensional matrix that provides a structural base to fill tissue lesion and provides cells with a suitable environment for proliferation and differentiation. Cell-seeded scaffolds can be implanted immediately or be cultured in vitro for a period of time before implantation. To obtain uniform cell growth throughout the entire volume of the scaffolds, an optimal strategy for cell seeding into tissue-engineering scaffolds is important. In this paper, we focus on a mathematical model considering nutrient diffusion and cell proliferation inside scaffolds. To overcome some discrepancy between the numerical results and experimental data of cell distribution in the scaffolds, we consider cell migration in our model. Also, we develop an efficient and accurate numerical scheme for a mathematical model to predict the growth and distribution of cells in scaffolds. Here, the proposed numerical algorithm is a hybrid method which uses both finite difference approximations and analytic closed-form solutions. Through the mathematical model and a hybrid numerical scheme, we present several numerical results in order to investigate effects of each model parameter. Moreover, we propose an optimization algorithm which finds the best set of model parameters that minimize a discrete l2-error between numerical and experimental data.

The shift-invert residual Arnoldi method and the Jacobi–Davidson method: theory and algorithms

ZHONGXIAO JIA
Tsinghua University, China
Email: jiazx@tsinghua.edu.cn

Using a new analysis approach, we establish a general convergence theory of the Shift-Invert Residual Arnoldi (SIRA) method for computing a simple eigenvalue nearest to a target σ and/or the associated eigenvector. In SIRA, a subspace expansion vector at each step is obtained by solving a certain inner linear system. We prove that the inexact SIRA method mimic the exact SIRA well provided that the inner linear systems are iteratively solved with *low* or *modest* accuracy. The results demonstrate that SIRA is superior to the inexact Shift-Invert Arnoldi (SIA) method, where the inner linear system involved must be solved with very high accuracy whenever the approximate eigenpair is of poor accuracy and are only solved with decreasing accuracy after the approximate eigenpair starts converging. Based on the theory, we design a practical stopping criterion for inner solvers. For practical purpose, we propose a restarted SIRA algorithm. Our analysis approach applies to the Jacobi–Davidson (JD) method as well, a general convergence theory is obtained similarly for the standard JD method with a fixed target, and a practical JD algorithm is developed. Numerical experiments confirm our theory and the considerable superiority of the (non-restarted and restarted) inexact SIRA to the inexact SIA, and demonstrate that the inexact SIRA and JD are similarly effective and mimic the exact SIRA very well.

The statistical and neural network models of birdsong syntax

DEZHE Z. JIN
The Pennsylvania State University, USA
Email: dzj2@psu.edu

Music and language consist of sequences of musical notes or words. The sequences follow rules with both restriction and flexibility. Bird songs of species such as the Bengalese finch have similar traits. With about ten syllable types, a Bengalese finch sings songs with syllable sequences that are variable but not random. Statistical analysis shows that the sequences can be described accurately using a probabilistic state transition model. A state is associated with a single syllable, but a syllable can be represented by multiple states. A state branches out to several states, and the next state is determined using the transition probabilities. A state sequence thus generated determines a syllable sequence. The transition probabilities can adapt if the states are repeated. The resulting model is a partially observable Markov model with adaptation (POMMA). The POMMA-generated syllable sequences are statistically equivalent to the observed syllable sequences. A POMMA can be mapped into a network model of the projection neurons in HVC (proper name), a critical pre-motor nucleus in the song control neural pathway. A state corresponds to a chain network of the HVC projection neurons. Spike propagation through the chain produces the associated syllable. A chain branches into other chains. At a branching point, the spikes select one of the connected chains to continue the propagation due to mutual inhibition mediated by the inhibitory HVC inter-neurons and noise. This selection corresponds to the probabilistic syllable transition. The model also allows influence of auditory feedback on the transition probabilities, which can adapt when a syllable is sung repeatedly. Recent experimental results support the branching chain neural network model of the song syntax in the Bengalese finch.

Mechanisms of long distance cell migration

PAUL M. KULESA* , REBECCA MCLENNAN, JASON MORRISON, KATE PRATHER, LOUISE DYSON, MICHELLE L. WYNN, SANTIAGO SCHNELL, RUTH E. BAKER, AND PHILIP K. MAINI
Stowers Institute for Medical Research, USA
Email: PMK@stowers.org

Migratory cells travel through many different microenvironments to pattern structures in the vertebrate embryo. One example is the neural crest, a multipotent, highly migratory cell population that travel long distances to contribute to head, heart, and trunk development. Cell lineage tracing has mapped neural crest cell migratory pathways and the time during which cells travel to peripheral targets. However, the mechanisms that direct neural crest cells over long distances is unclear.

We present an example that highlights the migration of neural crest cells to form the vertebrate sympathetic nervous system (SNS). Mistakes during neural crest migration and their SNS differentiation program contribute to birth defects that affect respiratory function and may result in neuroblastoma, an aggressive pediatric cancer. We present novel insights of chick neural crest cell migratory behaviors and dynamic gene expression changes during SNS formation, collected from in vivo dynamic imaging and gene profiling. We evaluate model mechanisms, using an agent-based approach, and discuss the results of closely integrated experiments and theory that lead us to a simple, mechanistic model of long distance cell migration.

One - dimensional solute dispersion along unsteady flow through heterogeneous medium: dispersion being proportional to square of velocity

ATUL KUMAR*[1], DILIP KUMAR JAISWAL[1], AND NAVEEN KUMAR[2]
*[1]Lucknow University, India
[2]Banaras Hindu University, India
Email: atul.tusaar@gmail.com

In the present work one – dimensional solute transport originating from a continuous uniform point source is studied along unsteady longitudinal flow through heterogeneous medium of semi-infinite extent. Velocity is considered as directly proportional to the linear spatially dependent function which defines the heterogeneity. It is also assumed temporally dependent. It is expressed in both the independent variables in degenerate form. Dispersion parameter

is considered proportional to square of the velocity. Certain new independent variables are introduced through separate transformations to reduce the variable coefficients of the advection – diffusion equation into constant coefficients. Then Laplace Transformation Technique (LTT) is used to get the desired solution. The effects of heterogeneity and unsteadiness, on the solute transport are studied.

Modeling renal hemodynamics: how the kidney regulates blood flow

ANITA T. LAYTON
Duke University, USA
Email: `alayton@math.duke.edu`

The kidney plays an essential role in the regulation of blood flow. We have formulated a mathematical model for the rat afferent arteriole (AA), glomerulus, and short loop of Henle, and used that model to study the interactions between the tubuloglomerular feedback (TGF) and myogenic mechanism, the two key mechanisms that mediate renal autoregulation. Blood flow is described by Poiseuille flow. The AA model consists of a series of arteriolar smooth muscle cells, each of which represents ion transport, cell membrane potential, cellular contraction, gap junction coupling, and wall mechanics. The myogenic response representation is based on the hypothesis that the voltage dependence of calcium channel openings responds to transmural pressure so that the vessel constricts when pressure increases. The glomerular filtration model is based on the model by Deen et al. (*Am J Physiol* 1972). The TGF model represents the pars recta, descending limb, and thick ascending limb, and predicts tubular fluid flow rate and $[Cl^-]$ along the loop. The model can be used as a fundamental component in a multi-scale renal microvasculature model for investigations of pathogenesis of hypertensive renal diseases.
This research was supported in part by NIH grant DK-89066 and NSF grant DMS-0715021.

A practical unconditionally gradient stable scheme for the N-component Cahn–Hilliard system

HYUN GEUN LEE* AND JUNSEOK KIM
Korea University, Korea
Email: `leeh@korea.ac.kr`

We present a practically unconditionally gradient stable conservative nonlinear numerical scheme for the N-component Cahn–Hilliard system modeling the phase separation of an N-component mixture. The scheme is based on a nonlinear splitting method and is solved by an efficient and accurate nonlinear multigrid method. And the scheme allows us to convert the N-component Cahn–Hilliard system into a system of $N-1$ binary Cahn–Hilliard equations and significantly reduces the required computer memory and CPU time. We observe that our numerical solutions are consistent with the linear stability analysis results. We also demonstrate the efficiency of the proposed scheme with various numerical experiments.

Fbi-transform-based Eulerian Gaussian beams for the Schrödinger equation

SHINGYU LEUNG
The Hong Kong University of Science and Technology, Hong Kong
Email: masyleung@ust.hk

We extend our previous work on the Fourier–Bros–Iagolnitzer (FBI)-transform-based Eulerian Gaussian beam method for solving the Schrödinger equation in the semi-classical regime by introducing the backward phase flow method. In this talk we aim at two crucial computational issues of the Eulerian Gaussian beam method: how to carry out long-time beam propagation and how to compute beam ingredients rapidly in phase space. By virtue of the FBI transform, we address the first issue by introducing the reinitialization strategy into the Eulerian Gaussian beam framework. Essentially we reinitialize beam propagation by applying the FBI transform to wavefields at intermediate time steps when the beams become too wide. To address the second issue, inspired by the original phase flow method, we propose the backward phase flow method which allows us to compute beam ingredients rapidly. Numerical examples demonstrate the efficiency and accuracy of the proposed algorithms.

Heat and moisture transport in fibrous porous media with condensation/evaporation and fiber absorption

BUYANG LI
City University of Hong Kong, Hong Kong
Email: libuyang@gmail.com

We study heat and sweat transport in porous textile media. In this application, heat, air and vapor transport are coupled in a rather complicated way and the physical process can be viewed as a nonisothermal, multiphase and multicomponent flow with complex phase changes in the form of evaporation/condensation and fiber absorption. We present a more precise mathematical formulation of condensation/evaporation with a truncated Hertz-Knudsen equation, which makes the model applicable in the general dry-wet case. To describe the absorption process by fiber in a wet environment more precisely, we introduce a flux type boundary condition for the fiber absorption equation, while the previous models with a simple saturated condition may not be realistic.

Numerical simulations are performed to compare with results from previous models and experimental data, with both finite difference methods and finite element methods. Several practical cases are simulated for clothing assemblies with the human thermoregulation system. Moreover, we provide optimal error estimates for an uncoupled finite difference method in one-dimensional space and a splitting finite element method in three-dimensional space. The error analysis lies on some interesting skills used in PDEs analysis and physical features in modelling.

The physical process of the sweat transport is governed by a system of nonlinear, degenerate and strongly coupled parabolic equations in general. However, mathematical analysis for those models is very limited due to the lack of reasonable link between modelling in engineering and analysis in mathematics. We prove existence of a classical solution for the steady-state

case and existence of weak solutions for the dynamic models with complex phase changes. The proof is based on the nature of gas convection in the mass equations and energy equation, with physically realistic assumptions. The analysis may be applied to the multicomponent heat and mass transport models in many other areas, and provides a fundamental tool for theoretical analysis of numerical methods.

Discontinuous Galerkin methods for Vlasov-Maxwell equations

FENGYAN LI
Rensselaer Polytechnic Institute, USA
Email: `lif@rpi.edu`

The Vlasov-Maxwell system is one of the important models to study collisionless magnetized plasmas. It couples the Vlasov equation satisfied by the distribution function of the particle(s) and the Maxwell system, and it has wide applications, ranging from space and laboratory plasmas, fusion, high-power microwave generation, and large scale particle accelerators. The simulation of Vlasov-Maxwell equations however is challenging, due to the high-dimensionality, multiple temporal and spatial scales, and the conservation of many important physical quantities. In this talk, I will present our recent progress in developing and analyzing discontinuous Galerkin methods for Vlasov-Maxwell equations.

Generalized Foldy–Lax formulation

PEIJUN LI
Purdue University, USA
Email: `lipeijun@math.purdue.edu`

We consider the scattering of a time-harmonic plane wave incident on a two-scale heterogeneous medium, which consists of scatterers that are much smaller than the wavelength and extended scatterers that are comparable to the wavelength. A generalized Foldy–Lax formulation is proposed to capture multiple scattering among point scatterers and extended scatterers. Our formulation is given as a coupled system, which combines the original Foldy–Lax formulation for the point scatterers and the regular boundary integral equation for the extended obstacle scatterers. An efficient physically motivated Gauss–Seidel iterative method is proposed to solve the coupled system, where only a linear system of algebraic equations for point scatterers or a boundary integral equation for a single extended obstacle scatterer is required to solve at each step of iteration.

Spectral methods for solving a fourth-order partial integro-differential equation with a weakly singular kernel

WULAN LI
Wenzhou Medical College, China
Email: liwulan@163.com

We consider spectral methods for the following fourth-order partial integro-differential equation with a weakly singular kernel, let $I = (-1,1)$ and $T \in R$ satisfy $0 < T < \infty$, which the form is

$$\begin{aligned} &u_t(t,x) + \int_0^t K(t-s)u_{xxxx}(s,x)ds - \int_0^t K(t-s)u_{xx}(s,x)ds \\ &= f(x,t), \qquad (x,t) \in I \times (0,T], \end{aligned} \tag{1}$$

along with the initial conditions

$$u(x,0) = \varphi(x), \quad x \in I, \tag{2}$$

and the boundary conditions

$$u(t,-1) = 0, \;\; u(t,1) = 0, \;\; u_x(t,-1) = 0, \;\; u_x(t,1) = 0, \;\; t \in (0,T], \tag{3}$$

Here, $K(t-s)$=$(t-s)^{\alpha-1}/\Gamma(\alpha)$. For the above integro-differential equation, The equation is discretized in space by the spectral method and in time by the finite central difference method and the Lagrange interpolated method, obtained a semi-discrete scheme and a fully discrete scheme; then proved the stability and convergence of the semi-discrete scheme. A numerical example demonstrates the theoretical results.

An outline of this paper is organized as follows: First, we introduce the weighted Sobolev spaces on I associated with the Jacobi weighted measure. We define a projection operator from the Jacobi weighted measures onto the space of polynomials with degree less than an integer N and an polynomial interpolation operator in section 2. Section 3 is concerned with the approximation of (1) by the spectral method and the weighted projection. As has been emphasized in this paper,we establish stability and convergence of the spectral method for (1). This method allows one to achieve high accuracy for smooth solution. Finally, a numerical example are carried out to support the theoretical results in section 4.

Some properties for generalized vector equilibrium problems

Y. C. LIN
China Medical University, Taiwan
Email: yclin@mail.cmu.edu.tw

In this talk, a new parametric generalized vector equilibrium problem (PGVEP, for short) is introduced and studied in Hausdorff topological vector spaces. The mappings of both efficient and weak efficient solutions for this problem are introduced.

First, we establish the results of existence for PGVEP and the compactness for the set of weak efficient solutions and the upper semi-continuity for the mappings of the weak efficient solution for PGVEP.

Next, by applying our some previous works, we discuss the existence of the efficient solutions and the structures of the efficient solutions set for PGVEP, such as compactness for the efficient solutions set and the upper semi-continuity for the mappings of efficient solutions for PGVEP. Furthermore, the connectedness for the efficient solutions set of PGVEP is also proved.

Finally, we give some examples to illustrate our main results. These results will show the convergent behavior about the sets of solutions by two kinds of parameters.

Near-cloak in acoustic scattering

HONGYU LIU
University of North Carolina at Charlotte, USA
Email: hliu28@uncc.edu

In this talk, we shall consider the near-invisibility cloaking in acoustic scattering by non-singular transformation media. A general lossy layer is included into our construction. We are especially interested in the cloaking of active/radiating objects. Our results on the one hand show how to cloak active contents more efficiently, and on the other hand indicate how to choose the lossy layer optimally.

Scattering and inverse scattering problems for acoustic waves by an obstacle with impedance boundary

JIJUN LIU
Southeast University, China
Email: jjliu@seu.edu.cn

The inverse scattering problems for acoustic waves or electromagnetic waves are of great importance both in mathematical theory and in engineering areas. For given incident wave and an obstacle, there will be scattered wave outside of the obstacle due to the reflection of obstacle boundary. The inverse scattering problems aim to detect the properties of the obstacle boundary, say, geometric shape and physical parameters on the boundary, from the information about the scattered waves. Mathematically, these problems can be described by corresponding inverse problems for Helmholtz equation or Maxwell equations under some assumptions.

The acoustic wave scattering for given incident wave by an impenetrable cylinder with infinite length in $\mathbb{R}^3$ can be governed by an exterior problem for 2-dimensional Helmholtz equation, with Sommerfeld radiation for the scattered wave at infinite place. The obstacle boundary may be sound-soft, sound-hard, or impedance type. The topic of this talk will focus on the implementable reconstruction scheme from finite number of measurement data for recovering the obstacle boundary.

Firstly, we introduce how to implement the probe method for the obstacle with impedance boundary, which belongs to the so-called "exact method". In the theoretical construction of this scheme, the far-field data for incident plane waves are applied to construct the scattered waves $\Phi^s(\cdot,z)$ corresponding to the point sources. Using $\Phi^s(\cdot,z)$, the Dirichlet to Neumann (DtN) map can be determined from which the indicator for the boundary shape is constructed. For this problem we give a theoretical analysis on the error estimate for the DtN map in

terms of the error of far field data. For reconstruction scheme, we give an efficient realization of the derivative of $\Phi^s(x,y)$ in terms of the reciprocity principle. Once the obstacle shape is determined, the surface impedance can be determined using moment method or boundary integral equation method.

Secondly, we introduce our recent work of reconstructing both obstacle shape and boundary impedance from far field data using the method of fundamental solution (MFS). This scheme belongs to the category of "approximate reconstruction". This method is originally developed for solving direct problems for which the fundamental solution to the PDE can be expressed explicitly. For inverse scattering problem, we firstly transform the far-field data into near field on a known cycle ∂G containing the unknown obstacle D. The exact nonlocal DtN condition can be set up on ∂G. Thus the scattered wave satisfies a boundary value problem for the Helmholtz equation in $G \setminus D$, with some additional condition in ∂G. Then the inverse problem can be stated as: identify $(\partial D, \lambda(x))$ using $u^s(x)|_{\partial G}$. For this problem, we express the solution $u^s(x)$ to PDE in terms of the combination of fundamental solution with source points outside of the domain $G \setminus \bar{D}$. Both the combination coefficients and the locations of point sources as well as $(\partial D, \lambda(x))$ are considered as the unknowns. Then we construct a nonlinear cost function in finite dimensional space with the discretization of $(\partial D, \lambda(x))$ and some regularizing terms. The approximation to $(\partial D, \lambda(x))$ is defined as the minimizer to the cost function. The existence and the convergence property of the minimizer are proven. Numerical tests have shown that this method is valid.

FDTD Techniques on overlapping cells and moving meshes

JINJIE LIU*[1], MOYSEY BRIO[2], AND JEROME V. MOLONEY[3]
*[1]Delaware State University, USA
[2,3]The University of Arizona, USA
Email: jliu@desu.edu

A stable anisotropic Finite-Difference Time-Domain (FDTD) algorithm based on overlapping cells is developed for solving Maxwell's equations of electrodynamics in anisotropic media. For complex media that include perfectly electric conductor (PEC) and anisotropic dielectric materials, such as the metamaterial cloaking devices, the conventional anisotropic FDTD method suffers from instability due to the interpolation in the finite-difference operator in the constitutive equations. The proposed method is stable as it relies on the overlapping cells to provide the collocated field values without any interpolation.

To simulate long-distance optical pulse propagation, we have developed a moving frame FDTD method with Perfectly Matched Layer (PML) boundary conditions. Good agreement between the moving and stationary FDTD methods is obtained for the pulse propagation in dielectric, dispersive, and nonlinear media.

Efficient boundary integral equation method for photonic crystal fibers

WANGTAO LU* AND YA YAN LU
City University of Hong Kong, Hong Kong
Email: lwangtao2@student.cityu.edu.hk

Photonic crystal fibers (PCFs) with many air holes and complicated geometries can be difficult to analyze using conventional waveguide mode solvers such as the finite element method. Boundary integral equation (BIE) methods are suitable for PCFs, since they formulate eigenvalue problems only on the interfaces and are capable of computing leaky modes accurately. To improve the efficiency, it is desirable to have high order BIE methods that calculate the minimum number of functions on the interfaces. Existing BIE methods calculate two or four functions on the interfaces, but high order implementations are only available for those with four functions. In this paper, a new high order BIE method is developed and it calculates two functions on the interfaces. Numerical results indicate that the new BIE method achieves exponential convergence and extremely high accuracy.

Numerical computation for scattering problems of near field by using of the ultra weak variational formulation

FUMING MA*, TIAN LUAN, ENXI ZHENG, AND MINGHUI LIU
Jilin University, China
Email: mfm@jlu.edu.cn

In this talk, we consider the scattering problem of near field in optics model. For numerical computation, we introduce an ultra-weak variational formulation. Then, we use some plane waves and evanescent waves as base of finite dimensional subspace and discrete our problem. The estimation of error and numerical examples are presented in talk.

Modelling aspects of tumour growth

PHILIP K. MAINI
University of Oxford, UK
Email: maini@maths.ox.ac.uk

We investigate a specific aspect of tumour cell invasion in which it is proposed that the cancer cells alter the environment to facilitate their invasion of host-tissue. This hypothesis, known as the acid-mediated cancer invasion model, arises from a study of a coupled system of non-linear partial differential equations. We extend and analyse this model in detail and further address the issue of whether the results of possible therapies arising from this hypothesis can be extended from mice to humans.

A rational Krylov method for a class of non-linear eigenvalue problems

KARL MEERBERGEN
Katholieke Universiteit Leuven, Belgium
Email: Karl.Meerbergen@cs.kuleuven.be

Polynomial eigenvalue problems are often solved by transforming them to a Companion-like form. This is a linear eigenvalue problem of larger size that can be solved by methods for linear eigenvalue problems. For the quadratic eigenvalue problem, this idea has led to the SOAR and Q-Arnoldi methods.

We will solve the non-linear eigenvalue problem $A(\lambda)x = 0$ by approximating $A(\lambda)$ by an interpolating polynomial. When we choose the polynomial basis well, we can apply a Krylov method in a dynamic way, i.e., we can choose the interpolation points during the Arnoldi run. We will discuss four choices of polynomial bases: monomials, Newton, Lagrange and Chebyshev polynomials. For each of these, we have a different method. We will elaborate in more detail a rational Krylov method using Newton polynomials. The Ritz values are computed from a small linear generalized eigenvalue problem using the QZ method. We will show a moment matching property, show a connection with Newton's method for the non-linear eigenvalue problem and discuss implementation details of the algorithm. Numerical examples will be given to illustrate the method.

This contribution is joint work with Roel Van Beeumen and Wim Michiels (KU Leuven, Belgium).

A stochastic variational inequality and applications to random vibrations and mechanical structures.

LAURENT MERTZ
The Chinese University of Hong Kong, Hong Kong
Email: lxmertz@gmail.com

This work is devoted to a stochastic variational inequality modeling a one dimensional elasto-plastic problem with noise. In an earlier work made by A. Bensoussan and J. Turi (Degenerate Dirichlet Problems Related to the Invariant Measure of Elasto-Plastic Oscillators, AMO,2008) the solution a stochastic variational inequality modeling an elasto-perfectly-plastic oscillator has been studied. The existence and uniqueness of an invariant measure has been proven. In this work, we present a new characterization of the invariant measure. The key finding is the connection between nonlocal PDEs and local PDEs which can be interpreted with short cycles of the Markov process solution of the stochastic variational inequality. Then, for engineering applications, we prove that the plastic deformation has a variance which increases linearly with time and we characterize the corresponding drift coefficient by defining long cycles behavior of the Markov process solution of the stochastic variational inequality.

Modelling in the biomedical and social sciences: from animal coat patterns to brain tumours to saving marriages

JAMES D. MURRAY
University of Oxford, UK; Princeton University, USA; University of Washington, USA
Email: jdmurray@princeton.edu; murrayj@maths.ox.ac.uk

The generation of pattern and form is still a challenging and major problem in the biomedical sciences. I shall describe three very different problems. First I shall briefly describe an early study on the complex, diverse and beautiful coat patterns on animals, and show how a reaction diffusion model helped to explain the wide diversity observed in the animal kingdom. I shall then describe a surprisingly informative model, now used clinically, for quantifying the growth of brain tumours, enhancing imaging techniques and quantifying individual treatment protocols prior to their use. Among other things, it is used to estimate patient life expectancy and explain why some patients live longer than others with the same treatment protocols. Finally I shall describe an example from the social sciences which quantifies marital interaction that is used to predict marital stability and divorce with surprising accuracy. It has helped design a new scientific marital therapy which is currently used in practice. (The talk will be understandable to a general scientific, rather than primarily for a mathematical, audience.)

The mathematics of choosing a new home; modelling nest site selection in honey bees

MARY R MYERSCOUGH
University of Sydney, Australia
Email: marym@maths.usyd.edu.au

In the spring a swarm of bees may leave the hive and settle on a branch of a tree while scouts go out and search for a new home. When a scout has found a new home she returns to the swarm and performs a waggle dance that advertises the location and quality of the potential new home. She then returns to the site and comes back to the swarm again to advertise the site. A scout may make several returns. The scoutsõ behaviour allow the swarm to make a collective decision about which is the best site available, even though no scout has visited more than one site. In this talk, I present a number of models that help us help us to understand how this process works. One model relies on ideas similar to matrix population models. Another is a simple differential equation model, similar to models for the spread of disease. The models show how the individual behaviour of scout bees generate a collective decision and suggest how honey bee colonies have adapted to the best possible decision independent of the size of the swarm and the availability of nest sites.

Pattern quarks and leptons

ALAN NEWELL
The University of Arizona, USA
Email: anewell@math.arizona.edu

The Standard Model endows its quarks and leptons with mass, fractional charge and spin by inserting the symmetries U(1), SU(2), SU(3) by hand into the governing Lagrangian.... While I do not suggest that the story I shall tell should in any way be considered a replacement for that staple of the physicist's diet, it is nevertheless interesting that objects with very similar properties appear, without the a priori insertion of any special symmetries other than those of rotational and translational invariance, as string or vortex like defects arising because of stress induced instabilities in a wide class of pattern forming systems. Moreover, each of the quantities that we associate with mass, charge and spin has a geometrical interpretation and can be related respectively to the condensation of the mean and sectional Guassian curvatures of the surfaces of constant phase of the pattern onto the defect cores.

Deformable image registration algorithm for intensity modulated radiation therapy(IMRT)

DOUGLAS KS NG[*1], SM WONG[2], AND FION WK CHEUNG[3]
[*1]City University of Hong Kong, Hong Kong
[2]Open University of Hong Kong, Hong Kong
[3]Queen Elizabeth Hospital, Hong Kong
Email: douglas.ng@ieee.org

The cause of death due to cancer has constantly been increasing during the last decades. The success in accurately localizing the target region close to tumor as well as avoiding damage to the nearby healthy organ (organs at risk) is crucial to control the tumor growth and minimize side effects to the patient. During the whole course of Radiation therapy treatment, some parametric changes such as the reduction of the patient's weight, the shrinkage of the tumor, and the edema of the tissue. These changes need some substantial modifications on the patient's anatomy before radiotherapy treatment. Therefore, an efficient registration method to delineate the clinically critical objects in computed tomography images obtained from the radiation treatment process is needed. Deformable image registration has undergone intensive investigation over the last decades and draw attention for researchers in the field of computer vision, and remote sensing, etc. Despite the significant progress that has been made, deformable registration remains a challenging problem in the field of radiotherapy.
This paper will present several version of deformation image registration algorithms, such as demons algorithm. Their performances in terms of both accuracy and efficiency will be compared and discussed.

SNMFCA: supervised NMF-based image classification and annotation

MICHAEL K. NG
Hong Kong Baptist University, Hong Kong
Email: mng@math.hkbu.edu.hk

In this paper, we propose a novel supervised nonnegative matrix factorization based framework for both image classification and annotation (SNMFCA). The framework consists of two phrases: training and prediction. In the training phrase, two supervised nonnegative matrix factorizations for image descriptors and annotation terms are combined together to identify the latent image bases, and represent the training images in the space spanned by the bases. These latent bases can capture the representation of the images in terms of both descriptors and annotation terms. Based on the new representation of training images, classifiers can be learnt and built. In the prediction phrase, a test image is first represented by the latent image bases via solving a linear least squares problem, and then the prediction for a new image classification and annotation can be done via the trained classifiers and the proposed annotation mapping model. In the algorithm, we develop a 3-block proximal alternating nonnegative least squares algorithm to determine the latent image bases, and show its convergent property. Extensive experiments on real-world image data sets suggest that the proposed framework is able to predict the label and annotation for testing images successfully. Experimental results have also shown that our algorithm is computationally efficient and effective for image classification and annotation.

Oldroyd model of viscoelastic fluids: some theoretical and computational issues

AMIYA KUMAR PANI
Indian Institute of Technology Bombay, India
Email: akp@math.iitb.ac.in

Newton's model of incompressible viscous fluid is described by the wellknown Navier-Stokes equations. This has been a basic model for describing flow at moderate velocities of majority of viscous incompressible fluids encountered in practice. However, models of viscoelastic fluids have been proposed in the mid twentieth century which take into consideration the prehistory of the flow and are not subject to Newtonian flow. One such model was proposed by J.G. Oldroyd and hence, it is named after him. The equation of motion in this case gives rise to the following integro-differential equation

$$\frac{\partial u}{\partial t} + u \cdot \nabla u - \mu \Delta u - \int_0^t \beta(t-\tau)\Delta u(x,\tau)\,d\tau + \nabla p = f(x,t),\ x \in \Omega, t > 0, (*)$$

and incompressibility condition

$$\nabla . u = 0,\ \ x \in \Omega, t > 0$$

with initial condition

$$u(x,0) = u_0, u = 0,\ x \in \partial\Omega, t \geq 0.$$

Here, Ω is a bounded domain in R^2 with boundary $\partial\Omega, \mu > 0$ and the kernel $\beta(t) = \gamma exp(-\delta t)$, where both γ and δ are positive constants. With a brief discussion on the model, we, in the

first part of this talk, concentrate on a recently derived uniform estimates in time whose proof was bothering us for the last 10 to 12 years. With a brief note on existence, we look into some new regularity results under realistically assumed conditions on the initial data. In the second part, we apply finite element Galerkin approximations to the above system and discuss convergence analysis without assuming compatibility conditions which are hard to verify while conducting numerical experiments. Since the problem (*) is an integral perturbation of the Navier-Stokes equations, we would like to discuss '*how far the results on finite element analysis for the Navier-Stokes equations can be carried over to the present case*.' We conclude the talk with some theoretical and computational issues.

Systemic risk

GEORGE PAPANICOLAOU
Stanford University, USA
Email: papanicolaou@stanford.edu

I will discuss some mathematical models for assessing the risk of systemic or overall failure in large, interconnected systems that evolve stochastically. I will also discuss applications, primarily in banking and finance.

New hybrid discontinuous Galerkin methods

EUN-JAE PARK
Yonsei University, Korea
Email: ejpark@yonsei.ac.kr

A new family of hybrid discontinuous Galerkin methods is studied for second-order elliptic equations [3,4]. Our proposed method is a generalization of CBE method [2] which allows high order polynomial approximations. Our approach is composed of generating PDE-adapted local basis and solving a global matrix system arising from a flux continuity equation. Our method can be viewed a hybridizable discontinuous Galerkin method [1] using a Bauman-Oden type local solver.

First, optimal order error estimates measured in the energy norm are proved for new triangular elements. Numerical examples are presented to show the performance of the method. Next, quadratic and cubic rectangular elements are proposed and optimal order error estimates measured in the energy norm are provided for elliptic equations [4]. Then, this approach is exploited to approximate Stokes equations. Numerical results are presented for various examples including the lid driven-cavity problem.

[1] B. COCKBURN, J. GOPALAKRISHNAN AND R. LAZAROV, *Unified hybridization of discontinuous Galerkin, mixed and continuous Galerkin methods for second order elliptic problems*, SIAM J. Numer. Anal. 47 (2009), pp. 1319–1365.

[2] Y. JEON AND E.-J. PARK, *Nonconforming cell boundary element methods for elliptic problems on triangular mesh*, Appl. Numer. Math. 58 (2008), pp. 800–814.

[3] Y. Jeon and E.-J. Park, *A hybrid discontinuous Galerkin method for elliptic problems*, SIAM J. Numer. Anal. 48 (2010), no. 5, 1968-1983.

[4] Y. Jeon and E.-J. Park, *New locally conservative finite element methods on a rectangular mesh*, To appear in Numerische Mathematik.

Droplet motion in one-component fluids on solid substrates with wettability and temperature gradients

TIEZHENG QIAN
The Hong Kong University of Science and Technology, Hong Kong
Email: maqian@ust.hk

I will report our recent works on diffuse-interface modeling of contact line motion in one-component liquid-gas systems on solid surfaces. We use the dynamic van der Waals theory to describe the continuum hydrodynamics with liquid-gas phase transition in the bulk region and derive the boundary conditions for dissipative processes at the fluid-solid interface. The positive definiteness of entropy production rate is the guiding principle of our derivation. Numerical simulations have been carried out to investigate the dynamic effects of the newly derived boundary conditions, showing that the contact line can move through both phase transition and boundary slip, with their relative contributions determined by a competition between the two coexisting mechanisms in terms of entropy production. The observed competition can be interpreted by the Onsager principle of minimum entropy production. Numerical results will be presented for droplet motion driven by wettability and temperature gradients on solid surfaces.

Energy stability analysis and adaptive time-stepping strategy for nonlinear diffusion equations

ZHONGHUA QIAO
The Hong Kong Polytechnic University, Hong Kong
Email: zqiao@inet.polyu.edu.hk

In this talk, I will review our recent works on some nonlinear diffusion equations, which have the dissipative mechanism in energy laws, such as, the dynamics of the molecular beam epitaxy (MBE) model, the Cahn-Hilliard model, the phase-field crystal model, etc. The numerical simulations of these models require very long time computations to reach the steady state. In our research, we have developed some unconditionally energy stable schemes which can preserve the discretized energy decay properties for these models. By using the energy stable schemes, an adaptive time-stepping strategy has been introduced. The energy is used to monitor the change of the time steps. Large time steps are used when the energy decays rapidly and small time steps are adopted otherwise. The numerical experiments demonstrated that the CPU time is significantly saved for long time simulations, and both the steady states and the dynamical behaviors are resolved accurately.

The Hankel rank of a sequence for algebraic extrapolation of short time series

MINVYDAS RAGULSKIS
Kaunas University of Technology, Lithuania
Email: minvydas.ragulskis@ktu.lt

We propose a new approach for the algebraic extrapolation of a numerical sequence based on the concept of the Hankel rank. It is important to note that the Hankel rank of a sequence is independent from the state-space realization of the system. It describes algebraic relationships between elements of the sequence without pretending to approximate the analytical model of an underlying dynamical system; moreover, these algebraic relationships are exact. We exploit the Hankel rank for the identification of the skeleton algebraic progression in the time series and use this information to forecast future values of that time series. A method for a short-term time series forecasting based on the identification of skeleton algebraic sequences is developed. It can be noted that this method is especially effective when the time series is short and there is insufficient data to train the neuro of fuzzy based systems. Such an approach helps to extract as much information about the process as possible and then use this information to extrapolate past behavior into future. Numerical experiments with an artificially generated and a real-world time series are used to illustrate the functionality of the proposed method.

Computation and applications of conformal modulus

ANTTI RASILA
Aalto University, Finland
Email: antti.rasila@iki.fi

Moduli of rings and quadrilaterals are frequently applied in geometric function theory, and these quantities are also useful in certain applications. We discuss numerical computation of the conformal moduli of quadrilaterals and ring domains with the hp-FEM algorithm [2]. Besides approximating the conformal modulus, the harmonic potential function can also be used for finding the canonical conformal mapping by using the harmonic conjugate [1]. We demonstrate that the hp-FEM algorithm applies to the case of non-polygonal boundary and report numerical results with error estimates. Applications of the algorithm to the so-called exterior modulus problem from [3] are discussed, and performance of is compared to other methods, e.g., the Schwarz-Christoffel mapping. We also discuss our recent work with more complicated domains, e.g., ring domains with fractal-like boundary, and construction of conformal mappings between multiply connected domains by using a generalization of the conjugate function method. This presentation is based on joint research with H. Hakula, T. Quach and M. Vuorinen.

[1] H. HAKULA, T. QUACH and A. RASILA, *Conjugate Function Method for Numerical Conformal Mappings*. arXiv:1103.4930.

[2] H. HAKULA, A. RASILA and M. VUORINEN, On moduli of rings and quadrilaterals: algorithms and experiments, *SIAM J. Sci. Comput.* **33** (2011) 279–302.

[3] H. HAKULA, A. RASILA and M. VUORINEN, COMPUTATION OF EXTERIOR MODULI OF QUADRILATERALS. arXiv:1111.2146.

Boundary conditions for the moving contact line problem

WEIQING REN
National University of Singapore; Institute of High Performance Computing, Singapore
Email: matrw@nus.edu.sg

I will talk about a contact line model derived from principles of non-equilibrium thermodynamics and molecular dynamics simulations. Macroscopic thermodynamic principles are used to place constraints on the form of the boundary conditions, and the detailed constitutive relations are computed from molecular dynamics. The contact line model consists of the Navier-Stokes equation, a boundary condition for the slip velocity, and a relation between the dynamic contact angle and the contact line velocity. The contact line model is used to study contact angle hysteresis on a chemically patterned solid surface.

Computationally efficient position-dependent smoothness-increasing accuracy-conservering (SIAC) filtering

XIAOZHOU LI AND JENNIFER K.RYAN*
Delft Technical University, The Netherlands
Email: J.K.Ryan@tudelft.nl

Computational efficiency is always a concern with the implementation of numerical methods. Such efficiency considerations can often make it difficult to implement superconvergence extraction techniques. In this talk we discuss improvements to position-dependent Smoothness-Increasing Accuracy-Conserving (SIAC) filtering to enhance the smoothness and accuracy of the discontinuous Galerkin (DG) methods and make it computationally efficient. For linear hyperbolic equations with a sufficiently smooth solution, this SIAC filter can improve the accuracy order from $k+1$ to $2k+1$, where k is the highest polynomial degree of the DG approximation.

The original position-dependent SIAC filter uses $2k+1$ central B-splines of order $k+1$ in the interior of the domain. By introducing a smooth shift function we can redefine the filter nodes that allow for application near boundaries. To reduce the error magnitude near the boundaries, the number of B-splines are also doubled in those regions. This results in a filter that is useful for linear hyperbolic equations throughout the domain. However, due to the use of the $4k+1$ central B-splines near the boundary regions, extra computational costs were observed, and worse yet was that this filter could no longer be implemented in double-precision; at least quadruple precision was required for post-processing polynomials $\mathscr{P}^k$ with $k \geq 3$. Furthermore, the large support of $5k+1$ elements causes problems when it is applied to equations whose solutions lack the high degree of regularity required, such as for nonlinear equations. However, it is possible to modify these ideas to obtain a computationally efficient SIAC filter that can be applied up to domain boundaries or near a discontinuity in the solution. This new filter maintains the same support size as the symmetric filter, making it more viable for GPU computing. Numerical results are presented for solutions of both linear and nonlinear equation solved on uniform and nonuniform meshes.

Perfectly matched layers conforming to triangular lattices for numerical simulations of photonic crystal devices

SHICHANG SHE* AND YA YAN LU
City University of Hong Kong, Hong Kong
Email: shichashe2@student.cityu.edu.hk

For simulating photonic crystal devices with a triangular lattice structure, it is advantageous to use hexagon unit cells and truncate the domain along the edges of these unit cells. The perfectly matched layer (PML) technique is widely used to absorb outgoing waves

Although a typical PhC device is non-periodic, it contains many identical unit cells. In the frequency domain, this feature has been exploited in the Dirichlet-to-Neumann (DtN) map method by constructing the DtN operator for each unit cell. Especially for the boundary cells. to complete constructing of boundary DtN, the DtN map method must apply proper artificial boundary conditions on the boundary of a finite computational domain.

in numerical simulations. A PML that conforms to triangular lattices is developed in this paper. More precisely, the PML is a layer that follows the edges of the hexagon unit cells along the boundary of the computational domain. To retain the high accuracy, we implement the PML using a pseudospectral method.

Recent progresses on quadrilateral nonconforming element methods

DONGWOO SHEEN
Seoul National University, Korea
Email: sheen@snu.ac.kr

Nonconforming elements have been used to replace expensive traditional conforming elements in solving fluid and solid mechanics. In this talk, we will review and introduce several nonconforming elements on quadrilateral and hexahedral meshes for elliptic, Stokes, and biharmonic problems, that have been developed with our collaborators. We discuss optimal error estimates and stability. Some numerical results will be presented.

Some recent advances on phase-field models for multiphase complex fluids

JIE SHEN
Purdue University, USA; Xiamen University, China
Email: shen7@purdue.edu

I shall present some recent work on phase-field model for multiphase complex fluids. Particular attention will be paid to develop models which are valid for problems with large density ratios and which obey an energy law.

I shall present efficient and accurate numerical schemes for solving the coupled nonlinear system for the multiphase complex fluid, in many case prove that they are energy stable, and show ample numerical results which not only demonstrate the effectiveness of the numerical schemes, but also validate the flexibility and robustness of the phase-field model.

Population cycles in voles: predators, seasonality and killer grass

JONATHAN A. SHERRATT
Heriot-Watt University, UK
Email: jas@ma.hw.ac.uk

In many parts of Northern Europe, voles exibit multi-year cycles in abundence. The traditional explanation for population cycles is predation, and this has a long history of study via mathematical models. I will show that the generation of cycles by predation is significantly complicated by the pronounced seasonal forcing in areas such as Scandinavia and Northern UK. I will describe the use of bifurcation theory of forced dynamical systems to explain the wide range of oscillatory behaviours that occur in seasonally forced predator prey systems. Recent field experiments suggests that predation is the driving force behind vole cycles in Scandinavia, but not in Northern UK. An alternative explanation is suggested by recent data indicating that the species of grass eaten by voles in Northern UK exhibits a defense response: after herbivory, its leaves regrow with an increased level of silica, which significantly reduces the nutritional benefit of the plant to voles. I will describe a mathematical model based on greenhouse experiments on the response of grass to herbivory, and laboratory data on the effect of dietary silica on voles. In the presence of seasonal forcing, the model predicts population cycles that closely resemble those seen in field data from Northern UK.

Calculation of periodic travelling wave stability: a users' guide

JONATHAN A. SHERRATT
Heriot-Watt University, UK
Email: jas@ma.hw.ac.uk

Periodic travelling waves (PTWs) (wavetrains) are an important solution type for many partial differential equations. Applications include hydrodynamics, solar cycles, oscillatory and excitable chemical reactions such as the Belousov-Zhabotinskii reaction, spatiotemporal patterns in cyclic populations, and banded vegetation patterns in semi-arid environments. PTWs occur in families, with some members of the family being stable and others being unstable. I will describe a new method for the numerical determination of PTW stability, in which the essential spectrum is calculated via numerical continuation. I will go on to describe how numerical continuation can be used to trace boundaries in parameter space between stable and unstable PTWs; the results that I will discuss include the first calculation of a stability boundary for which the change in stability is of Hopf type. I will discuss the application of the methods to a number of real problems. All of the computational methods that I will describe are implemented in the new, freely available software package WAVETRAIN, which I will discuss.

Positivity-preserving high order schemes for convection dominated equations

CHI-WANG SHU
Brown University, USA
Email: shu@dam.brown.edu

We give a survey of our recent work with collaborators on the construction of uniformly high order accurate discontinuous Galerkin (DG) and weighted essentially non-oscillatory (WENO) finite volume (FV) and finite difference (FD) schemes which satisfy strict maximum principle for nonlinear scalar conservation laws, passive convection in incompressible flows, and nonlinear scalar convection-diffusion equations, and preserve positivity for density and pressure for compressible Euler systems. A general framework (for arbitrary order of accuracy) is established to construct a simple scaling limiter for the DG or FV method involving only evaluations of the polynomial solution at certain quadrature points. The bound preserving property is guaranteed for the first order Euler forward time discretization or strong stability preserving (SSP) high order time discretizations under suitable CFL condition. One remarkable property of this approach is that it is straightforward to extend the method to two and higher dimensions on arbitrary triangulations. We will emphasize recent developments including arbitrary equations of state, source terms, integral terms, shallow water equations, high order accurate finite difference positivity preserving schemes for Euler equations, and positivity-preserving high order finite volume scheme and piecewise linear DG scheme for convection-diffusion equations. Numerical tests demonstrating the good performance of the scheme will be reported.

Multiscale approximation with compactly supported RBFs

IAN H SLOAN
University of New South Wales, Australia
Email: i.sloan@unsw.edu.au

Because physical phenomena on the earth's surface occur on many different length scales, it makes sense when seeking an efficient approximation to start with a crude approximation followed by a sequence of corrections on finer and finer scales. The idea we consider here is to use a sequence of point sets with decreasing mesh norm, and a sequence of compactly supported radial basis functions centred at the points, with the RBFs having smaller and smaller length scale. In this way we can obtain an approximation of any desired accuracy in an efficient and stable manner. The idea of a multiscale scheme like this has appeared previously, for example in papers of Schaback and of Narcowich/Schaback/Ward, Floater/Iske, and Hales/Levesley, and in books and papers of Freeden and colleagues, but there seems to be no previous analysis of a multiscale approximation based on scaled versions of a single compactly supported RBF and scattered data. In this talk I shall outline the ideas behind the analysis of the multiscale scheme, illustrate the method with a problem from geophysics, and discuss how best to choose the sequences of point sets and scales. The talk describes joint work with Q. Thong Le Gia and Holger Wendland, including an extension to PDEs.

Black–Scholes prices and hedges for financial derivatives in non-Gaussian non-martingale models

TOMMI SOTTINEN
University of Vaasa, Finland
Email: tommi.sottinen@uwasa.fi

The so-called Black–Scholes model is the classical pricing model for financial derivatives such as call-options. While the model is widely used, it is also widely acknowledged that its assumptions are not true in the real markets. Indeed, the Black–Scholes model assumes that the returns of the underlying asset are independent and Gaussian. In reality they are neither, but exhibit many so-called stylized facts.

We show that the pricing and hedging formulas implied by the Black–Scholes model are still true in the presence of many stylized facts, such as long-range dependence and non-Gaussian marginals. In fact, we show that probabilistic properties of the underlying asset are mostly irrelevant in pricing financial derivatives. The only important assumption of the pricing model is the so-called quadratic variation that is sometimes also called the volatility. However, the volatility must be understood in the pathwise sense as small-time scale fluctuations of the realized underlying asset path and not as a long-time scale estimator of the variance of the underlying asset process. In the Black–Scholes model these two concepts of course coincide, but in general they don't.

Hydrodynamics of self-propulsion near boundaries

SAVERIO SPAGNOLIE* AND ERIC LAUGA
Brown University, USA
Email: Saverio_Spagnolie@brown.edu

The swimming kinematics and trajectories of many microorganisms are altered by the presence of nearby boundaries, be they solid or deformable, and often in perplexing fashion. When an organism's swimming dynamics vary near such boundaries a question arises naturally: is the change in behavior biological, fluid mechanical, or perhaps mediated by other physical laws? Of interest then is a general framework for determining the extent to which fluid mechanics passively alter swimming behaviors in the presence of a wall. To this end, we explore a far-field description of swimming organisms and provide a general framework for studying the fluid-mediated modifications to swimming trajectories, and consider trapped/escape trajectories and equilibria for model organisms of varying shape and propulsive activity. This framework may help to explain surprising behaviors observed in the swimming of many microorganisms and synthetic swimming devices.

An eigenvalue method using multiple frequency data

JIGUANG SUN
Delaware State University, USA
Email: jsun@desu.edu

Dirichlet and transmission eigenvalues have important applications in qualitative methods in inverse scattering. Motivated by the fact that these eigenvalues can be obtained from scattering data, we propose a new method using multiple frequency data (EM^{2}F). The method detects eigenvalues and builds indicator functions to reconstruct the support of the target. Numerical reconstruction is quite satisfactory. Estimation of Dirichlet or transmission eigenvalues is obtained. Furthermore, reconstruction of and estimation of eigenvalues can be combined together to distinguish between the sound soft obstacle and non-absorbing inhomogeneous medium.

Simulation of flow and transport in subsurface carbon sequestration using conservative finite element methods

SHUYU SUN
King Abdullah University of Science and Technology, Saudi Arabia
Email: shuyu.sun@kaust.edu.sa

Subsurface flow and transport in porous media has important applications in petroleum reservoir engineering and environmental science. One important application is the injection of CO_2 in subsurface reservoirs for carbon sequestration, which is becoming increasingly attractive due to issues related to global warming. In addition, CO_2 injection to water-flooded hydrocarbon reservoirs is also of interest for improved hydrocarbon recovery. Modeling equation system of such multiphase flow and transport can be generally split into 1) an elliptic partial differential equation (PDE) for the pressure and 2) one or multiple convection dominated convection-diffusion PDE for the saturation or for the chemical composition. Accurate simulation of the phenomena not only requires local mass conservation to be retained in discretization, but it also demands steep gradients to be preserved with minimal oscillation and numerical diffusion. The heterogeneous permeability of the media often comes with spatially varied capillary pressure functions, both of which impose additional difficulties to numerical algorithms. To address these issues, we solve the saturation equation (or species transport equation) by discontinuous Galerkin (DG) method, a specialized finite element method that utilizes discontinuous spaces to approximate solutions. Among other advantages, DG possesses local mass conservation, small numerical diffusion, and little oscillation. The pressure equation is solved by either a mixed finite element (MFE) scheme, a DG scheme, or a Galerkin finite element method with local conservative postprocessing. In this talk, we will present the theory and numerical examples of this combined finite element approach for simulating subsurface multiphase flow. We will also discuss our on-going work where Darcy-scale simulations are coupled with pore-scale and molecule-scale simulations.

Flow control problems for heat convection model

DMITRY TERESHKO
Institute of Applied Mathematics FEB RAS, Russia
Email: ter@iam.dvo.ru

Flow control problems are considered as a special branch of hydrodynamics with a large number of important applications. There are numerous objectives of control, e.g., flow matching, drag minimization, lift enhancement, preventing transition to turbulence, enhancing or deterring mixing, etc. Mathematically, such an objective is expressed as a cost functional. In order to meet these objectives one usually applies injection or suction of fluid at some sections of the boundary.

Since we want to use temperature bounadary controls we consider the model of heat transfer in a viscous incompressible heat-conducting fluid. The model consists of the Navier-Stokes equation and the convection-diffusion equation for temperature that are nonlinearly related via buoyancy in the Boussinesq approximation and via convective heat transfer. Mathematical model describes the constraints of the minimization problem.

Solving flow control problems we find state and control variables that minimize the objective functional subject to the requirement that the constraints are satisfied. In the framework of the considered mathematical model the state variables are the velocity, pressure and temperature – the mechanical and thermodynamic variables that describe the flow. The control variables could be the velocity vector, temperature and heat flux on some parts of the boundary. These problems are examples of constrained optimization problems. Such problems may be rewritten as unconstrained optimization problems through the Lagrange multiplier method. The first-order necessary conditions result in an optimality system from which optimal states and controls may be determined. The optimality system is a large system of nonlinear partial differential equations for the basic state, adjoint state and control, so its theoretical and numerical analysis is difficult.

Numerical algorithm based on Newton's method is proposed for numerical solution of the nonlinear optimality system. The open source software freeFEM++ is used for the discretization of boundary-value problems by the finite element method. Some computational results connected with the vorticity minimization in 2D viscous fluid flow by means of the temperature and hydrodynamic boundary controls are given and analyzed.

How Chebfun solves ODEs and eigenvalue problems

LLOYD N. TREFETHEN
University of Oxford, UK
Email: trefethen@maths.ox.ac.uk

Chebfun has become a remarkably powerful tool for solving differential equations and eigenvalue problems in one dimension. This talk will describe some of the algorithms that make this possible, which are mainly due to Ásgeir Birkisson, Toby Driscoll, and Nick Hale. In particular we will focus on

- the "happiness iteration" underlying Chebfun adaptivity

- rectangular spectral collocation discretizations
- how EIGS selects its eigenfunctions
- Fréchet derivative operators for nonlinear problems via AD
- the graphical user interface CHEBGUI

Imaging models based on surface plasmon resonances data

FAOUZI TRIKI
Université Joseph Fourier, France
Email: Faouzi.Triki@imag.fr

In this talk we study two imaging models which use surface plasmon resonances (SPR). These imaging methods are simple and allow for a limited real time biomolecular sensing. Mathematically, these models often lead to ill-posed spectral inverse problems.

Parallel computing for pilot-scale field of CO_2 geologic storage in taiwan

CHIEN-HAO TSENG*, CHIA-CHEN KUO, CHUAN-LIN LAI, FANG-AN KUO, AND CHIH-WEN CHANG
National Center for High-Performance Computing, Taiwan
Email: c00how00@nchc.narl.org.tw

Carbon-Dioxide Capture and Storage (CCS) in deep saline aquifers is one of the most feasible techniques for reducing anthropogenic emission of CO_2. To resolve the problem of large-scale and long-term CO_2 inject into the geologic formation, we need to consider the CO_2 plume migration and leakage phenomena in the saline aquifer. In this paper, a high-performance parallel computing is used to simulate the large-scale and long-term CO_2 geologic storage at the saline aquifer in the west basin of Taiwan, at which 1 million ton/year of CO_2 is injected. The dimension of the pilot-scale field is around 3420 km^2 and 2.5 km deep. The simulation software, TOUGH2-MP, is installed on an IBM 1350 Cluster, which is composed of 404 nodes and 2 Intel Woodcrest 3.0 Ghz Dual-Core processors per node. The simulation results demonstrate that the high-speed parallel computing enhance the capability on handling a large-scale model. In the simulation, the CO_2 migrated 4.2 km from the injection point toward Taiwan Strait within the observed 150 years. The amount of dissolved CO_2 in the brine formation increased with time. Our results indicate that the test field is a potential site for the CO_2 geologic storage.

Global asymptotic dynamics in a coupled neural network with delays

JUI-PIN TSENG
National Pingtung University of Education, Taiwan
Email: jptseng@mail.npue.edu.tw

This work presents an effective approach to study global asymptotic dynamics, including the synchronization and convergence of dynamics, for the coupled neural networks. The present approach is nonstandard, as compared to the Lyapunov function approach and monotone dynamics theory; under the framework, the problem of establishing the synchronization or convergence for delayed coupled nonlinear systems reduces to solving a corresponding system of linear equations. We illustrate the approach with a neural network that consists of a pair of sub-networks. Each sub-network is a one-way loop with K neurons and the whole network is of two-way coupling between a single neuron of each loop. Each loop has an internal delay and the connection between the loops has a transmission delay. We study the synchronization and asymptotic synchronous phases of this network. Some delay-dependent and delay-independent criteria are derived for global synchronization, anti-phase motion, global convergence to zero or multiple synchronous equilibra, as well as bifurcation which yields synchronous periodic solutions. Our investigation also provides theoretical support to some numerical findings in the literature.

Trefftz difference schemes and non-asymptotic Trefftz-Whitney homogenization

IGOR TSUKERMAN
The University of Akron, USA
Email: itsukerman@uakron.edu

Several examples of a curious interplay between analytical and numerical methods are presented. First, local Trefftz approximations are used to construct high-order difference schemes for elliptic and hyperbolic problems in homogeneous, piecewise-homogeneous and inhomogeneous media. Second, Whitney-like interpolation, well established in finite element analysis, is put to a new use in a semi-analytical non-asymptotic homogenization theory of periodic structures with an arbitrary (i.e. not necessarily vanishingly small) lattice cell size. The non-asymptotic theory is applied to electromagnetic metamaterials and explains, in particular, "optical magnets" – artificial magnetism at high frequencies.

Inverse heat equation

KIM TUAN VU
University of West Georgia, USA
Email: vu@westga.edu

We are concerned with the recovery of coefficients $q(x), \alpha(b), \beta(b)$, and $v(t)$ (in case $p(x)$ is

known) or $p(x)$ (in case $v(t)$ is known) in the multidimensional heat conduction problem described by

$$\begin{cases} u_t(x,t) = \Delta u(x,t) + q(x)u(x,t) + v(t)p(x), \quad x \in \Omega \subset \mathbb{R}^m,\ m \geq 2 \\ \alpha(b)\frac{\partial u}{\partial \nu}(b,t) + \beta(b)u(b,t) = 0 \ \text{ for } \ b \in \partial\Omega \text{ and } t > 0, \\ u(x,0) = f(x) \in L^2(\Omega), \end{cases} \tag{1}$$

where Ω is a bounded domain, ν is the outer unit normal vector on the boundary, and $\alpha(b) + \beta(b) \neq 0$ on $\partial\Omega$.

We introduce a new method which makes no use of the classical tools such as the Boundary Control method or the Faddeev's exponential growing solutions. Instead we show that certain Fourier coefficients can be extracted from measurements on the boundary. More importantly they can be extracted from measurements at a single point on the boundary.

Let b_1 be a fixed, but arbitrary point on the boundary $\partial\Omega$. We prove, for the Neumann problem (1), that the initial-to-Dirichlet lateral measurements $u^f(b_1,t)$ for $t \in (0,T)$, for countably many initial data f, are enough for the recovery of unique q, α, β, and p or v. Similarly the initial-to-Neumann lateral measurements $\frac{\partial u^f(b_1,t)}{\partial \nu}$, $t \in (0,T)$, determines q, α, β, and p or v. uniquely for the Dirichlet problem (1). Moreover, our proof also provides an algorithm to recover q, α, β, p and v.

In the one-dimensional case we show that for any $q \in L_1$, we can recover a unique q after a finite number of measurements at end points. If an upper bound for $\|q\|_1$ is known, then we would know explicitly the maximum number of required measurements. If a lower bound of q is known a priori, a suitable choice of two initial conditions, a power and a step functions, is enough to recover the heat coefficient q.

Robustness of biological tissue patterning

FREDERIC Y.M. WAN
University of California (Irvine), USA
Email: fwan@math.uci.edu

Biological tissue patterning involves binding of particular protein molecules, called morphogens, to specific signaling receptors on the surface of cells. The concentration of morphogen-receptor complexes (called bound morphogens for short) varies with locations, generally decreasing away from the localized morphogen source. The bound morphogen gradient trigers the genetic program of the cells to differentiate from each other and form patterns. This basic patterning process is sensitive to environmental changes such as temperature variations. Yet biological patterns in nature are known to be stable. An effort is being made to uncover the mechanisms responsible for the robustness of biological patterns. Our findings show that the issues are many and complex. For example, conventional negative feedback mechanisns alone do not lead to robustness. This talk reports some of our results in this area that help to delineate the issues and how we have addressed them.

Inverse problems for elasticity, thin plate, and shallow shell equations by boundary measurements

JENN-NAN WANG
National Taiwan University, Taiwan
Email: jnwang@math.ntu.edu.tw

In this talk, I would like to discuss several inverse boundary value problems for 2D elasticity, thin plate, and shallow shell equations. The main theme is to investigate the relations between these inverse problems.

An efficient adaptive method for the phase field simulation of moving contact line problem

XIAO-PING WANG
The Hong Kong University of Science and Technology, Hong Kong
Email: mawang@ust.hk

In this talk, I will describe a newly developed phase field model for two phase fluid flow based on Cahn Hilliard Navier Stokes equation with generalized Navier boundary condition. Then I will describe an efficient adaptive method for the model. Several numerical results will then be presented.

Understanding the impact of public health policy: a contribution using mathematical models

JANE WHITE
University of Bath, UK
Email: K.A.J.White@bath.ac.uk

To be effective, public health policy must be responsive to health risks whilst maintaining economic viability. A costly intervention, whilst effective in reducing illness, may not be implemented; conversely, a cheaper alternative may be too ineffective in reducing illness to warrant its use. In the case of infectious disease control, policy decisions are further confounded by the need to be responsive to unexpected increases in incidence. Mathematical modelling can contribute to the decision making process, allowing different intervention strategies to be explored.
In this talk I will discuss recent intervention strategies which have been implemented in the UK to reduce incidence of two sexually transmitted infections: HPV and Chlamydia. In the first case, a prophylactic vaccination strategy has been initiated which targets girls aged 12-13. In the second case, a screening programme has been implemented which aims to increase screening rates without explicit discussion of goals in terms of anticipated change in infection prevalence.
Using mathematical models, I will address the following generic questions, motivated by the two sexually transmitted infections, with the model outcomes interpreted in a general context:

- How does a gender-specific vaccination programme compare with universal coverage?
- How does waning immunity impact the efficacy of a prophylactic vaccination programme?
- How do public health goals translate into measurable outputs?
- How does an optimal vaccination strategy vary according to public health goals?

Propagation of stable nonlinear beams in a finite nematic liquid crystal cell

A.A. MINZONI[1], L. W. SCIBERRAS[2], N. F. SMYTH[3], AND A. L. WORTHY*[4]
[1]Universidad Nacional Autónoma de México, México
[2]University of Wollongong, Australia
[3]University of Edinburgh, UK
*[4]University of Wollongong, Australia
Email: annette_worthy@uow.edu.au

Stable nonlinear optical beams, both solitary waves, termed nematicons, and optical votices, can form in a nematic liquid crystal due to a balance between the "huge" nonlinear optical rotational response of the nematic molecules and the diffractive spreading of the optical beam. The "huge" optical nonlinearity of a nematic makes it ideal for observing nonlinear effects over millimetre distances and for the development of photonic devices. The underlying principle of much of this experimental work and photonic device development is the control and manipulation of the beam trajectory.

In this work, the evolution of a nonlinear optical beams, both solitary waves and optical vortices, within a finite nematic liquid crystal cell will be analysed. The (linear) response of the nematic to the light will be found using both Fourier series and the method of images. The method of images has not been previously used in this context and is found to possess distinct advantages over the usual Fourier series method. In particular, it is found that very few images are needed to obtain a good approximation to the nematic response, in contrast to the number of terms needed in a Fourier series. Based on these Fourier and method of images solutions, an approximate theory will be developed for the evolution of the optical beam and excellent agreement is found with full numerical solutions of the governing nematicon equations. Finally, the contrasting effect of the cell boundaries on a nematicon and a vortex is explored. It is found that a vortex is unstable on close approach to the cell boundary, in contrast to a nematicon. This vortex instability is confirmed by a stability analysis.

Pre-asymptotic error analysis of CIP-FEM and FEM for Helmholtz equation with high wave number

HAIJUN WU* AND LINGXUE ZHU
Nanjing University, China
Email: hjw@nju.edu.cn

The continuous interior penalty finite element method (CIP-FEM) and the FEM for the Helmholtz equation in two and three dimensions are considered. Pre-asymptotic error estimates are derived for both methods under the condition of $\frac{kh}{p} \leq C_0\left(\frac{p}{k}\right)^{\frac{1}{p+1}}$, where k is the wave number, h is the mesh size, and C_0 is a constant independent of k, h, p, and the penalty parameters. It is shown that the pollution errors of both methods in H^1-norm are $O(k^{2p+1}h^{2p})$ if $p = O(1)$ and are $O\left(\frac{k}{p^2}\left(\frac{kh}{\sigma p}\right)^{2p}\right)$ if the exact solution $u \in H^2(\Omega)$ which coincide with existent dispersion analyses for the FEM on Cartesian grids. Here σ is a constant independent of k, h, p, and the penalty parameters. Moreover, it is proved that the CIP-FEM is stable for any $k, h, p > 0$ and penalty parameters with positive imaginary parts. Besides the advantage of the absolute stability of the CIP-FEM compared to the FEM, the penalty parameters may be tuned to reduce the pollution effects.

Asymptotic analysis of a viscous drop falling under gravity

JONATHAN WYLIE
City University of Hong Kong, Hong Kong
Email: mawylie@cityu.edu.hk

Despite extensive research on extensional flows, there is no complete explanation of why highly viscous fluids falling under gravity can form such persistent and stable filaments. We therefore investigate the motion of a slender axisymmetric viscous drop that is supported at its top by a fixed horizontal surface and extends downward under gravity. We consider the full initial-boundary-value problem for arbitrary initial shape of the drop in the case in which inertia and surface tension are initially negligible. We show that, eventually, the accelerations in the thread become sufficiently large that the inertial terms become important. We therefore keep the inertial terms and obtain asymptotic solutions for the full initial-boundary-value problem. The asymptotic procedure requires a number of novel techniques and the resulting solutions exhibit surprisingly rich behavior. The solution allows us to understand the mechanics that underlies highly persistent filaments.

Randomized sparse direct solvers and applications

JIANLIN XIA
Purdue University, USA
Email: xiaj@math.purdue.edu

We propose some new structured direct solvers for large sparse linear systems, using randomization and other techniques. Our work involves new flexible methods to exploit structures in

large matrix computations. Our randomized structured techniques provide both improved efficiency and much better flexibility than some existing structured sparse solvers. New efficient ways are proposed to conveniently perform various complex operations which are difficult in standard structured solvers. Extension of the techniques to least squares problems and eigenvalue problems will also be shown.

We also study the following issues:

1. Develop matrix-free structured solvers.
2. Update a structured factorization when few matrix entries change.
3. Relaxed rank requirements in structured solvers. We show the feasibility of our methods for solving various difficult problems, especially 2D/3D PDEs such as Helmholtz equations.
4. Develop effective preconditioners for problems without significant rank structures. We analyze the criterion for compressing off-diagonal blocks so as to achieve nearly optimal effectiveness and efficiency in our preconditioner.

Discontinuous Galerkin methods for the nonlinear Schrödinger equation

YINHUA XIA
University of Science and Technology of China, China
Email: yhxia@ustc.edu.cn

In this talk, we will present a discontinuous Galerkin (DG) finite element method for the nonlinear Schröding equation. The variational form is obtained after integrating by parts twice. L^2 Stability is proved by choosing the interfacial numerical fluxes carefully. The prior error estimated shows that this DG scheme gives the optimal orders of convergence in one dimensional space. Numerical examples shows that the scheme attains the optimal order of convergence for one and two dimensional spaces.

Mathematical modeling and analysis of mortgages

DEJUN XIE
Xi'an Jiaotong Liverpool University, China
Email: dejun.xie@xjtlu.edu.cn

In this work, we provide a mathematical model to value the fixed rate mortgage where the borrower is granted the right to close the contract early by paying off the outstanding loan balance all at once. The problem is formulated as a free boundary problem where the free boundary defines the level of market interest rate at which the borrower should make early payment. Integral equations are formulated to represent the contract value embedded with an unknown early payment boundary. Effective and robust numerical algorithms are designed and tested on the basis of the integral equation formulation. Certain analytical and numerical features of the model will be discussed. Highly accurate analytical formulas are derived to approximate the solution to the problem. Finally, we will generalize the technique and illustrate its applications to the other option pricing problems.

Conservative discontinuous Galerkin methods for the generalized Korteweg-de Vries equations

YULONG XING
Oak Ridge National Laboratory, USA; University of Tennessee, USA
Email: xingy@math.utk.edu

The Korteweg-de Vries (KdV) equation is a nonlinear mathematical model for the unidirectional propagation of waves in a variety of nonlinear, dispersive media. Recently it has attracted increasing attention as test-bed for the competition between nonlinear and dispersive effects leading to a host of analytical issues such global existence and finite time blowup, etc.

In this presentation, we construct, analyze, and numerically validate a class of conservative discontinuous Galerkin schemes for the generalized KdV equation. The schemes preserve the first two invariants (the integral and L2 norm) of the numerical approximations. We provide numerical evidence that this property imparts the approximations with beneficial attributes such as more faithful reproduction of the amplitude and phase of traveling wave solutions.

Uniform l^1 behavior for the numerical solutions of Volterra equations

DA XU
Hunan Normal University, China
Email: daxu@hunnu.edu.cn

In this talk, we study the numerical solutions of Volterra equations. The considered time discretization methods are the linear multi-step methods, space ones are the Galerkin finite element methods. The uniform l^1 stability and convergence for time discretization are given in the $l_t^1(0, \infty; H) \bigcap l_t^\infty(0, \infty; H)$ norm. Error estimates for the space Galerkin finite element solutions are presented in the norm of $L_t^1(0, \infty; L_x^2)$.

Multigrid methods of discontinuous Galerkin discretization for time-dependent fourth-order problems

YAN XU
University of Science and Technology of China, China
Email: yxu@ustc.edu.cn

In this paper, we explore a few efficient linear solver and time discretization methods coupled with the local discontinuous Galerkin(LDG) spatial discretization to solve linear time-dependent fourth-order equations. We use implicit time discretization formulations to solve the difficulty of a unreasonably small time step for an explicit local time stepping method. The multigrid methods and domain decomposition method are introduced to solve the resulting discrete system of implicit methods. The Fourier analysis method are used to analyze the convergence behavior of the multigrid method. Comparisons are made among the multigrid solver and other solvers, to conclude that multigrid solver is efficient when coupled with the LDG spatial discretization for solving linear time-dependent fourth-order equations.

Snakes and isolas in nonreversible conservative systems

YANCONG XU* AND BJORN SANDSTEDE
Hangzhou Normal University, China
Email: Yancongx@163.com

Reversible variational partial differential equations such as the Swift-Hohenberg equation can admit localized stationary roll structures whose solution branches are bounded in parameter space but unbounded in function space, with the width of the roll plateaus increasing without bound along the branch: this scenario is commonly referred to as snaking. In this work, the structure of the bifurcation diagrams of localized rolls is investigated for variational but nonreversible systems, and conditions are derived that guarantee snaking or result in diagrams that either consist entirely of isolas.

Parameterized maximum principle preserving flux limiters for high order scheme solving hyperbolic conservation laws: one-dimensional scalar problem

ZHENGFU XU
Michigan Technological University, USA
Email: zhengfux@mtu.edu

I will describe a class of parameterized limiters used to achieve strict maximum principle for high order numerical schemes applied to hyperbolic conservation laws computation. By decoupling a sequence of parameters embedded in a group of explicit inequalities, the numerical fluxes are locally redefined, therefore consistent and conservative. I will show that the global maximum principle can be preserved while the high order accuracy of the underlying scheme being maintained. The parameterized limiters are less restrictive on the CFL number when

applied to high order finite volume scheme. The less restrictive limiters allow for the development of the finite difference high order scheme which preserves the maximum principle. Within the proposed parameterized limiters framework, by relaxing the limits on the intermediate values of the multi-step Runge-Kutta method, a successive sequence of limiters allow for significant large CFL number. Numerical results and preliminary analysis for linear and nonlinear scalar problems are presented to support the claim. The parameterized limiters are applied to the numerical fluxes directly. There is no increased complexity to apply the parameterized limiters to different kinds of monotone numerical fluxes.

Computing exponentials of essentially non-negative matrices entrywise to high relative accuracy

JUNGONG XUE* AND QIANG YE
Fudan University, China
Email: xuej@fudan.edu.cn

A real square matrix is said to be essentially non-negative if all of its off-diagonal entries are non-negative. It has recently been shown that the exponential of an essentially non-negative matrix is determined entrywise to high relative accuracy by its entries up to a condition number intrinsic to the exponential function (Numer. Math. 110 (2008), 393–403). Thus the smaller entries of the exponential may be computed to the same relative accuracy as the bigger entries. This paper develops algorithms to compute exponentials of essentially non-negative matrices entrywise to high relative accuracy.

On existence of periodic solutions for the Duffing equation with impulses

XUXIN YANG
Hunan First Normal University, China
Email: yangxx2002@sohu.com

Many evolution processes are characterized by the fact that they experience abrupt changes in their state. These processes are subject to short-time perturbations whose duration is negligible in comparison with the duration of the process. Consequently, it is natural to assume that these perturbations act instantaneously, that is, in the form of impulses. It is known, for example, that many biological phenomena involving thresholds, bursting rhythm models in medicine and biology, optimal control models in economics, pharmacokinetics and frequency modulated systems, do exhibit impulsive effects. Thus impulsive differential equations, that is, differential equations involving impulse effects, appear as a natural description of observed evolution phenomena of several real world problems.

In its original form, the Duffing equation is a non-linear second-order ODE which is used in physics to model oscillators. It is a well-known example of a dynamical system exhibiting chaotic behavior. In this presentation, we discuss the existence of solutions to the Duffing-type equation given by W.Y. Ding,

$$x'' + g(x) = f(x,t),$$

with impulses. We obtain the sufficient condition of existence of infinitely many solutions, by means of the Poincaré-Birkhoff fixed point theorem under given conditions. Our results generalize those of T.R. Ding. We also give an example to illustrate how these results can be applied.

This presentation is based on joint research with Weibing Wang and Jianhua Shen. Our work has been supported by the NNSF of China (10871062), Scientific Research Fund of Hunan Provincial Education Department (10B017) and Hunan Provincial Natural Science Foundation of China (09JJ3010).

Computing eigenvalues of symmetric diagonally dominant matrices accurately with applications to differential operators

QIANG YE
University of Kentucky, USA
Email: qye@ms.uky.edu

For matrix eigenvalue problems arising in discretizations of differential operators, it is usually smaller eigenvalues that well approximate the eigenvalues of the differential operators and are of interest. The finite difference discretization leads to a standard eigenvalue problem $Ax = \lambda x$ and the finite element method results in a generalized eigenvalue problem $Ax = \lambda Bx$, where A (and B) are often diagonally dominant. With the condition number for the discretized problem A (or $B^{-1}A$) typically large, smaller eigenvalues computed are expected to have low relative accuracy.

In this talk, we present our recent works on high relative accuracy algorithms for computing eigenvalues of diagonally dominant matrices. We present an algorithm that computes all eigenvalues of a symmetric diagonally dominant matrix to high relative accuracy. We further consider using the algorithm in an iterative method for a large scale eigenvalue problem and we show how smaller eigenvalues of finite difference discretizations of differential operators can be computed accurately. Numerical examples are presented to demonstrate the high accuracy achieved by the new algorithm.

A phase-field model for tissue regeneration in a cartilage-hydrogel model

ANA YUN* AND JUNSEOK KIM
Korea University, Korea
Email: ana7123@korea.ac.kr

A phase-field model is proposed and an accurate numerical method is developed for regeneration of articular cartilage in a localized defect region. A cylindrical cartilage explant is assumed and it has a removed core region which is replaced with a nutrient-rich hydrogel. We use a phase-field model to capture the interface of the hydrogel and cartilage where the hydrogel turns into newly generated cartilage. Moreover, we present an accurate numerical method to have the numerical solutions in the phase field model and reaction–diffusion equations for

the nutrient and the newly generated cartilage. A variety of numerical simulations are performed to show the effect of parameters of our mathematical model including the temporal evolution of each variables. Moreover, numerical simulations based on biological mechanisms are investigated.

Estimates for the scattering from an EM cavity

KiHyun YUN
Hankuk University of Foreign Studies, Korea
Email: kihyun.yun@gmail.com

In this talk, we consider a time harmonic scattering problem of electromagnetic waves from a two-dimensional open cavity embedded in the infinite ground plane. Ammari, Bao and Wood reduced the scattering problems into a bounded domain (the cavity) problems. The stabilities of the solution to the bounded domain problems shall be presented in this talk. So far, little is known about stability of the solution in wave propagation with explicit dependence on the wave number. However, our stability estimates provide the explicit dependence on the high wave number.

The factorization method for reconstructing a penetrable obstacle with unknown buried objects

Jiaqing YANG, Bo ZHANG *, and Haiwen ZHANG
Chinese Academy of Sciences, China
Email: b.zhang@amt.ac.cn

This talk considers the problem of scattering of time-harmonic acoustic plane waves by an inhomogeneous penetrable obstacle with buried objects inside. This type of problems occurs in various areas of applications such as radar, remote sensing, geophysics, and nondestructive testing.

Let D_0 denote an impenetrable obstacle which is embedded in an inhomogeneous penetrable obstacle D characterized by the refractive index $n \in L^\infty(D)$ with $\mathrm{Re}[n] > 0$ and $\mathrm{Im}[n] \geq 0$, that is, $\overline{D_0} \subset D$. Assume that $\mathbb{R}^3 \setminus \overline{D}$ is filled with a homogeneous material with the refractive index 1. Then the scattering of time-harmonic acoustic waves by D and D_0 can be modeled by the Helmholtz equation with boundary conditions on the interface ∂D and boundary ∂D_0:

$$\Delta u + k^2 u = 0 \qquad \text{in } \mathbb{R}^3 \setminus \overline{D} \tag{1}$$

$$\Delta v + k^2 n v = 0 \qquad \text{in } D \setminus \overline{D_0} \tag{2}$$

$$u^s - v = f_1,\ \frac{\partial u^s}{\partial \nu} - \lambda \frac{\partial v}{\partial \nu} = f_2 \qquad \text{on } \partial D \tag{3}$$

$$\mathscr{B} v = 0 \qquad \text{on } \partial D_0 \tag{4}$$

$$\lim_{r\to\infty} r\Big(\frac{\partial u^s}{\partial r} - iku^s\Big) = 0 \qquad r = |x|, \tag{5}$$

where ν is the unit outward normal to the interface ∂D and boundary ∂D_0, λ is a complex constant. Here, the total field $u = u^s + u^i$ is given as the sum of the unknown scattered wave

u^s which is required to satisfy the Sommerfeld radiation condition (5) and the incident plane wave $u^i = e^{ikx\cdot d}$, where d is the incident direction and k is the positive wave number given by $k = \omega/c$ in terms of the frequency ω and the sound speed c in the region $\mathbb{R}^3\backslash\overline{D}$. On the interface ∂D, the so-called "transmission condition" (3) is imposed, which represents the continuity of the medium and equilibrium of the forces acting on it, where the boundary data $f_1 = -u^i$, $f_2 = -\partial u^i/\partial\nu$. The boundary condition $\mathscr{B}(v) = 0$ on ∂D_0 represents a Dirichlet, Neumann, impedance or mixed-type boundary condition depending on the physical property of the obstacle D_0.

The Sommerfeld radiation condition (5) implies an asymptotic behavior for the scattered field u^s of the form

$$u^s(x;d) = \frac{e^{ik|x|}}{|x|}\left\{u^\infty(\widehat{x};d) + O\left(\frac{1}{|x|}\right)\right\}, \qquad |x| \longrightarrow \infty$$

uniformly with respect to all directions $\widehat{x} = x/|x|$.

In this talk we will prove that the factorization method can be applied to reconstruct the interface ∂D with unknown buried objects. The factorization method was first suggested by Kirsch for inverse obstacle scattering problems and has been extended and improved continuously since then (see A. Kirsch and N. Grinberg *The Factorization Methods for Inverse Problems*, Oxford University Press, 2008). Precisely, defining the far field operator $F : L^2(\Omega) \mapsto L^2(\Omega)$ by

$$(Fg)(\widehat{x}) = \int_\Omega u^\infty(\widehat{x};d)g(d)ds(d), \qquad \widehat{x} \in \Omega,$$

where Ω is a sphere in $\mathbb{R}^3$, we prove the following characterization of the penetrable obstacle D.

Theorem. Assume that $\lambda > 0\,(\lambda \neq 1)$ or $\lambda = 1/n$ with $n \equiv n_0$ (some constant with $\mathrm{Im}(n_0) > 0$ satisfying that $\mathrm{Re}(n_0) > |n_0|^2$ or that $1 < \mathrm{Re}(n_0) < |n_0|^2$). For $z \in \mathbb{R}^3$ define $\phi_z \in L^2(\Omega)$ by $\phi_z(\widehat{x}) = e^{-ik\widehat{x}\cdot z}$, $\widehat{x} \in \Omega$. Then $z \in D$ if and only if $\sum_{j=1}^\infty |(\phi_z, \psi_j)_{L^2(\Omega)}|^2/\lambda_j < \infty$, or equivalently,

$$W(z) := \left(\sum_{j=1}^\infty \frac{|(\phi_z,\psi_j)_{L^2(\Omega)}|^2}{\lambda_j}\right)^{-1} > 0,$$

where $\{\lambda_j, \psi_j\}_{j\in\mathbb{N}}$ is an eigen-system of $F_\# := |\mathrm{Re}(F)| + \mathrm{Im}(F)$.

Numerical examples are provided to illustrate the inversion algorithm.

A new formulation of finite difference WENO scheme with Lax-Wendroff time discretization for conservation laws

Jiang Yan, Chi-Wang Shu, and Mengping Zhang*
University of Science and Technology of China, China
Email: mpzhang@ustc.edu.cn

We develop a new finite difference WENO scheme with Lax-Wendroff time discretization to solve conservation laws. In this scheme, the WENO interpolation of the solution and its derivatives are used to directly construct the numerical flux, instead of the usual practice of reconstructing the flux functions. Even though this procedure is more expensive than the usual practice, it does have several advantages. The first advantage is that arbitrary monotone fluxes can be used in this framework, while the traditional practice of reconstructing flux functions can be applied only to smooth flux splitting. The second advantage, which is fully explored in this work, is that it is more straightforward to construct a Lax-Wendroff time discretization procedure, with a Taylor expansion in time and with all time derivatives replaced by spatial derivatives, resulting in a narrower effective stencil compared with previous high order finite difference WENO scheme based on the reconstruction of flux functions with a Lax-Wendroff time discretization. We will describe the scheme formulation and present numerical tests for one- and two-dimensional scalar and system conservation laws demonstrating the designed high order accuracy and non-oscillatory performance of the scheme.

Low rank matrix approximation with graph regularization

ZHENYUE ZHANG* AND KEKE ZHAO
Zhejiang University, China
Email: zyzhang@zju.edu.cn

Low-rank matrix factorization plays an important role in data analysis such as dimension reduction, data compression, feature extraction, and information retrieval. The low-dimensional representation of high-dimensional data facilitates the linear structure retrieval or feature selection of data. However, the classical low-rank factorization ignores possible nonlinearities behind data. In this talk, we propose a graph regularized model of low-rank matrix factorization to preserve the nonlinear structures of data. We show that the new regularization model has globally optimal solutions in a closed form. A direct algorithm and an alternating iterative algorithm with inexact inner iteration are proposed to solve the regularized model to discriminatingly handle data with small or large number of points in column. We give a convergence analysis to prove the global convergence of the proposed iterative algorithm. Efficiency and precision of the algorithm on clustering and classification are numerically demonstrated via six real-world data sets. Performance comparison with existing algorithms also shows the effectiveness of the proposed method for low-rank factorization in general.

Modeling nonlinear dendritic integration using integrate-and-fire neuronal frameworks

DOUGLAS ZHOU
Shanghai Jiao Tong University, China
Email: zdz@sjtu.edu.cn

It has been discovered recently in experiments that the dendritic integration of excitatory glutamatergic inputs and inhibitory GABAergic inputs in hippocampus CA1 pyramidal neurons obeys a simple arithmetic rule as $V_S^{\mathrm{Exp}} \approx V_E^{\mathrm{Exp}} + V_I^{\mathrm{Exp}} + kV_E^{\mathrm{Exp}} V_I^{\mathrm{Exp}}$, where V_S^{Exp}, V_E^{Exp} and V_I^{Exp} are the amplitude of the summed somatic potential (SSP), the excitatory postsynaptic potential (EPSP) and the inhibitory postsynaptic potential (IPSP) measured at the time when the

EPSP reaches its peak value, respectively. Moreover, the shunting coefficient k only depends on the spatial location of excitatory and inhibitory inputs on the dendrite. We demonstrate both theoretically and numerically that the above dendritic integration rule can be explained by sub-threshold membrane potential dynamics as characterized in the conductance-based integrate-and-fire (I&F) model. In order to account for the spatial dependence of the shunting coefficient k, we propose a dendritic-integration-rule-based integrate-and-fire (DIF) model. Our analytical and numerical results show that this model is able to capture many experimental observations.

A novel meshless method for solving integral equations

HUA ZOU* AND HUA LI
Nanyang Technological University, Singapore
Email: zouh0001@e.ntu.edu.sg

The present work is to develop a novel strong-form meshless method for solving the generalized integral equations, which is called the Random Integral Quadrature (RIQ) method. The RIQ method combines the generalized integral quadrature (GIQ) technique and the Kriging interpolation technique together. By the RIQ method, the governing equations are firstly discretized with the GIQ technique over a set of background virtual nodes, and then the function values of the virtual nodes are approximated over a set of field nodes with Local Kriging method. By using the Kriging interpolation function, the field nodes can be distributed either randomly or uniformly, regardless of the regular or irregular domain. Several numerical examples are given to validate the method.

Some direct and indirect sampling methods for inverse obstacle / medium scattering problems

JUN ZOU
The Chinese University of Hong Kong, Hong Kong
Email: zou@math.cuhk.edu.hk

In this talk we shall present some recently developed direct and indirect sampling methods for numerical reconstruction of obstacles or inhomogeneous media in inverse scattering problems. Both near fields and far fields can be applied in these methods. Two- and three-dimensional numerical experiments will be presented. This is a joint work with Kazufumi Ito (NCSU) and Bangti Jin (Texas A&M). The work was substantially supported by Hong Kong RGC grants (projects 405110 and 404611).

LIST OF PARTICIPANTS

Gennady ALEKSEEV
Far Eastern Federal University, Russia
alekseev@iam.dvo.ru

Xavier ANTOINE
Univrsity of Lorraine, France
Xavier.Antoine@iecn.u-nancy.fr

Paul J. ATZBERGER
Univrsity of California (Santa Barbara), USA
atzberg@math.ucsb.edu

Gang BAO
Zhejiang University, China; Michigan State University, USA
bao@math.msu.edu

Timo BETCKE
University College London, UK
t.betcke@ucl.ac.uk

Pankaj BISWAS
Birla Institute of Technology and Science, India
pankaj.biswas2002@gmail.com

Rafael BORGES
Hong Kong Baptist University, Hong Kong
thalasyus@gmail.com

Messaoud BOULBRACHE
Sultan Qaboos University, Oman
boulbrac@squ.edu.om

Roman BRIZITSKII
Institute of Applied Mathematics, Russia
mlnwizard@mail.ru

David CAI
Shanghai Jiao Tong University, China; New York University, USA
cai@cims.nyu.edu

Michael K.H. CHAN
The University of Hong Kong, Hong Kong
mkhchan@hkucc.hku.hk

Raymond CHAN
The Chinese University of Hong Kong, Hong Kong
rchan@math.cuhk.edu.hk

Chih-Wen CHANG
National Center for High-Performance Computing, Taiwan
0903040@nchc.narl.org.tw

Xiao-Wen CHANG
McGill University, Canada
chang@cs.mcgill.ca

Bihong CHEN
Shenzhen University, China
cbhmath@hotmail.com

Shyan-Shiou CHEN
National Taiwan Normal University, Taiwan
sschen@ntnu.edu.tw

Xiaojun CHEN
The Hong Kong Polytechnic University, Hong Kong
maxjchen@polyu.edu.hk

Jin CHENG
Fudan University, China
jcheng@fudan.edu.cn

Fion WK CHEUNG
The Hong Kong Polytechnic University, Hong Kong
fioncheung210@yahoo.com.hk

Alexandre J. CHORIN
University of California (Berkeley), USA
chorin@math.berkeley.edu

Ching-Shan CHOU
Ohio State University, USA
chou@math.ohio-state.edu

Eric King-wah CHU
Monash University, Australia
eric.chu@sci.monash.edu.au

Eric Tsz Shun CHUNG
The Chinese University of Hong Kong, Hong Kong
tschung@math.cuhk.edu.hk

James DEMMEL
University of California (Berkeley), USA
demmel@cs.berkeley.edu

Jian DENG
University of Alberta, Canada
jdeng@math.ualberta.ca

Yuhui DENG
Harbin Institute of Technology Shenzhen Graduate School, China
ivandengyh@gmail.com

Wai Sun DON
Hong Kong Baptist University, Hong Kong
wsdon@hkbu.edu.hk

Kui DU
Xiamen University, China
kuidu@xmu.edu.cn

Bjorn ENGQUIST
The University of Texas at Austin, USA
engquist@math.utexas.edu

Graeme FAIRWEATHER
American Methamtical Society, USA
gxf@ams.org

Daniel FORGER
University of Michigan, USA
forger@umich.edu

Zhiming GAO
Institute of Applied Physics and Computational Mathematics, China
dtgaozm@gmail.com

Christophe GEUZAINE
University of LiÃÍge, Belgium
cgeuzaine@ulg.ac.be

Manfred HAMMER
University of Twente, The Netherlands
m.hammer@ewi.utwente.nl

Daihai HE
The Hong Kong Polytechnic University, Hong Kong
daihai.he@inet.polyu.edu.hk

Wen-Ming HE
Wenzhou University, China
he_wenming@yahoo.com.cn

Yu Sing HON
The Hong Kong University of Science and Technology, Hong Kong
seanyshon@gmail.com

Dan HU
Shanghai Jiao Tong University, China
hudan80@sjtu.edu.cn

Zhen HU
Hohai University, China
huzhen1230@gmail.com

Baojun HUANG
Huaibei Normal University, China
huangbaojun006-6@163.com

Dilip Kumar JAISWAL
Lucknow University, India
dilip3jais@gmail.com

Darae JEONG
Korea University, Korea
tinayoyo@korea.ac.kr

Zhongxiao JIA
Tsinghua Universiy, China
jiazx@tsinghua.edu.cn

Jinfeng JIANG
City University of Hong Kong, Hong Kong
jinjiang@cityu.edu.hk

Dezhe JIN
The Pennsylvania State University, USA
dzj2@psu.edu

Paul KULESA
Stowers Institute for Medical Research, USA
PMK@stowers.org

Atul KUMAR
Lucknow University, India
atul.tusaar@gmail.com

Anita LAYTON
Duke University, USA
alayton@math.duke.edu

Hyun Geun LEE
Korea University, Korea
leeh@korea.ac.kr

Shingyu LEUNG
The Hong Kong University of Science and Technology, Hong Kong
masyleung@ust.hk

Buyang LI
City University of Hong Kong, Hong Kong
libuyang@gmail.com

Fengyan LI
Rensselaer Polytechnic Institute, USA
lif@rpi.edu

Peijun LI
Purdue University, USA
lipeijun@math.purdue.edu

Wenbin LI
The Hong Kong University of Science and Technology, Hong Kong
lwb@ust.hk

Wulan LI
Wenzhou Medical College, China
liwulan@163.com

Wenyuan LIAO
University of Calgary, Canada
wliao@ucalgary.ca

Yen-Cherng LIN
China Medical University, Taiwan
yclin@mail.cmu.edu.tw

Hongyu LIU
University of North Carolina at Charlotte, USA
hliu28@uncc.edu

Jijun LIU
Southeast University, China
jjliu@seu.edu.cn

Jinjie LIU
Delaware State University, USA
jliu@desu.edu

Wangtao LU
City University of Hong Kong, Hong Kong
lwangtao2@student.cityu.edu.hk

Fuming MA
Jilin University, China
mfm@jlu.edu.cn

Philip MAINI
University of Oxford, UK
maini@maths.ox.ac.uk

Karl MEERBERGEN
Katholieke Universiteit Leuven, Belgium
Karl.Meerbergen@cs.kuleuven.be

Laurent MERTZ
The Chinese University of Hong Kong, Hong Kong
lxmertz@gmail.com

James D. MURRAY
University of Oxford, UK; University of Washington, USA; Princeton University, USA
jdmurray@princeton.edu
murrayj@maths.ox.ac.uk

Mary MYERSCOUGH
University of Sydney, Australia
marym@maths.usyd.edu.au

Alan NEWELL
The University of Arizona, USA
anewell@math.arizona.edu

Douglas KS NG
City University of Hong Kong, Hong Kong
douglas.ng@ieee.org

Michael NG
Hong Kong Baptist University, Hong Kong
mng@math.hkbu.edu.hk

Tuen Wai NG
The University of Hong Kong, Hong Kong
ntw@maths.hku.hk

Bamidele OYETUNDE
Petroleum Training Institute, Nigeria
oyetundebs@yahoo.com

Samares PAL
University of Kalyani, India
samaresp@yahoo.co.in

Amiya PANI
Indian Institute of Technology Bombay, India
akp@math.iitb.ac.in

George PAPANICOLAOU
Stanford University, USA
papanicolaou@stanford.edu

Eun-Jae PARK
Yonsei University, Korea
ejpark@yonsei.ac.kr

Tiezheng QIAN
The Hong Kong University of Science and Technology, Hong Kong
maqian@ust.hk

Zhonghua QIAO
The Hong Kong Polytechnic University, Hong Kong
zqiao@inet.polyu.edu.hk

Minvydas RAGULSKIS
Kaunas University of Technology, Lithuania
minvydas.ragulskis@ktu.lt

Antti RASILA
Aalto University, Finland
antti.rasila@iki.fi

Weiqing REN
National University of Singapore and Institute of High Performance Computing, Singapore
matrw@nus.edu.sg

Jennifer RYAN
Delft Technical University, The Netherlands
J.K.Ryan@tudelft.nl

Shichang SHE
City University of Hong Kong, Hong Kong
shichashe2@student.cityu.edu.hk

Dongwoo SHEEN
Seoul National University, Korea
sheen@snu.ac.kr

Jie SHEN
Purdue University, USA; Xiamen University, China
shen7@purdue.edu

Jonathan SHERRATT
Heriot-Watt University, UK
jas@ma.hw.ac.uk

Chi-Wang SHU
Brown University, USA
shu@dam.brown.edu

Ian SLOAN
University of New South Wales, Australia
i.sloan@unsw.edu.au

Tommi SOTTINEN
University of Vaasa, Finland
tommi.sottinen@uwasa.fi

Saverio SPAGNOLIE
Brown University, USA
Saverio_Spagnolie@brown.edu

Jiguang SUN
Delaware State University, USA
jsun@desu.edu

Shuyu SUN
King Abdullah University of Science and Technology, Saudi Arabia
shuyu.sun@kaust.edu.sa

Tao TANG
Hong Kong Baptist University, Hong Kong
ttang@hkbu.edu.hk

Robert TENZER
University of Otago, New Zealand
robert.tenzer@otago.ac.nz

Dmitry TERESHKO
Institute of Applied Mathematics, Russia
ter@iam.dvo.ru

Lloyd N. TREFETHEN
University of Oxford, UK
trefethen@maths.ox.ac.uk

Faouzi TRIKI
University Joseph Fourier, France
Faouzi.Triki@imag.fr

Chien-Hao TSENG
National Center for High-Performance Computing, Taiwan
c00how00@nchc.narl.org.tw

Jui-Pin TSENG
National Pingtung University of Education, Taiwan
jptseng@mail.npue.edu.tw

Igor TSUKERMAN
The University of Akron, USA
itsukerman@uakron.edu

Kim Tuan VU
University of West Georgia, USA
vu@westga.edu

Frederic Y. M. WAN
University of California (Irvine), USA
fwan@math.uci.edu

Jenn-Nan WANG
National Taiwan University, Taiwan
jnwang@math.ntu.edu.tw

Xiao-Ping WANG
The Hong Kong University of Science and Technology, Hong Kong
mawang@ust.hk

Jane WHITE
University of Bath, UK
K.A.J.White@bath.ac.uk

Sze Mui Anita WONG
The Open University of Hong Kong, Hong Kong
anwong@ouhk.edu.hk

Annette WORTHY
University of Wollongong, Australia
annette_worthy@uow.edu.au

Haijun WU
Nanjing University, China
hjw@nju.edu.cn

Jonathan WYLIE
City University of Hong Kong, Hong Kong
mawylie@cityu.edu.hk

Jianlin XIA
Purdue University, USA
xiaj@math.purdue.edu

Yinhua XIA
University of Science and Technology of China, China
yhxia@ustc.edu.cn

Dejun XIE
Xian Jiaotong Liverpool University, China
dejun.xie@xjtlu.edu.cn

Yulong XING
University of Tennessee, USA
xingy@math.utk.edu

Da XU
Hunan Normal University, China
daxu@hunnu.edu.cn

Yan XU
University of Science and Technology of China, China
yxu@ustc.edu.cn

Yancong XU
Hangzhou Normal University, China
Yancongx@163.com

Zhengfu XU
Michigan Technological University, USA
zhengfux@mtu.edu

Jungong XUE
Fudan University, China
xuej@fudan.edu.cn

Wenjing YAN
Xi'an Jiaotong University, China
wenjingyan@mail.xjtu.edu.cn

Xuxin YANG
Hunan First Normal University, China
yangxx2002@sohu.com

Qiang YE
University of Kentucky, USA
qye@ms.uky.edu

Xu Yi
University of Electronic Science and Technology of China, China
674227431@qq.com

Guoqiao YOU
The Hong Kong University of Science and Technology, Hong Kong
gyou@ust.hk

Ana YUN
Korea University, Korea
ana7123@korea.ac.kr

KiHyun YUN
Hankuk University of Foreign Studies, South Korea
kihyun.yun@gmail.com

Bo ZHANG
Chinese Academy of Sciences, China
b.zhang@amt.ac.cn

Mengping ZHANG
University of Science and Technology of China, China
mpzhang@ustc.edu.cn

Zhenyue ZHANG
Zhejiang University, China
zyzhang@zju.edu.cn

Chuwei ZHOU
The Hong Kong Polytechnic University, Hong Kong
07813646d@connect.polyu.hk

Douglas ZHOU
Shanghai Jiao Tong University, China
zdz@sjtu.edu.cn

Hua ZOU
Nanyang Technological University, Singapore
zouh0001@e.ntu.edu.sg

Jun ZOU
The Chinese University of Hong Kong, Hong Kong
zou@math.cuhk.edu.hk