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A3 Foresight Program
The 5th Joint Workshop

Mathematics of Biology, Fluid Dynamics and Material Sciences

Lakai Sandpine Hotel, Gangneung, S. Korea
October 17-20, 2018

Organized by

Hyeonbae Kang (Inha, Chair)
Jaekyoung Kim (KAIST)
Yasumasa Nishiura (Tohoku)
Jinhae Park (Chungnam National)
Sung-Ik Sohn (Gangneung-Wonju National)
Pingwen Zhang (Peking)

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Inha University

Program

Registration. Oct. 17, 4:00-8:00, Lakai Sandpine Hotel

Session 1. Oct. 18, 9:00-10:30 Chair. Hyeonbae Kang

9:00-9:30, Hisashi Okamoto (Gakushuin University)
Numerical computation of water waves on two vortical layers

9:30-10:00, Chuanju Xu (Xiamen University)
Efficient Numerical Methods for the Inextensible Immersed Interface in Incompressible Flows

10:00-10:30, Ran Zhang (Jilin University)
A weak Galerkin finite element scheme for the Cahn-Hilliard equation

Coffee Break, 10:30-10:50

Session 2. Oct. 18, 10:50-11:50 Chair. Pingwen Zhang

10:50-11:20, Yangjin Kim (Konkuk University)
The role of microenvironment in regulaNon of cell infiltraNon and bortezomib-OV therapy in glioblastoma

11:20-11:50, Masakazu Akiyama (Hokkaido University)
A mathematical model of collective cell migrations based on cell polarity

Lunch, 11:50-1:30

Session 3. Oct. 18, 1:30-3:00 Chair. Yasumasa Nishiura

1:30-2:00, Sanghyeon Yu (ETH)
Surface plasmons of geometrically singular structures

2:00-2:30, Xiaofei Li (Zhejiang University of Technology)
On the construction of weakly neutral inclusions

2:30-3:00, Daisuke Kawagoe (Inha University)
Spectral structure of the Neumann–Poincaré operator on tori

Coffee Break, 3:00-3:20

Session 4. Oct. 18, 3:20-4:50 Chair. Kei-Ichi Ueda

3:20-3:50, Masao Doi (Beihang University)
How to choose the best solution in the application of Onsager's variational principle

3:50-4:20, Lei Zhang (Peking University)
Solution landscapes of Nematic Liquid Crystal

4:20-4:50, Jinhae Park(Chungnam National University)
Some properties of Liquid Crystals

Poster Session, 4:50-6:30

Dinner, 6:30

Session 5. Oct. 19, 9:00-10:30 Chair. Jinhae Park

9:00-9:30, Masaharu Nagayama (Hokkaido University)
Theoretical analysis of a mathematical model for a self-propelled motion

9:30-10:00, Narina Jung (Department of Mechanical Engineering, UNIST)
Oscillatory motions of colloidal particles in an evaporating droplet containing surfactant

10:00-10:30, Tatsuya Mikami (Tohoku University)
Percolation on homology generators in codimension 1

Coffee Break, 10:30-10:50

Session 6. Oct. 19, 10:50-11:50 Chair. Lei Zhang

10:50-11:20, Jaekyoung Kim (KAIST)
Beyond the century of the Michaelis-Menten equation

11:20-11:50, Kei-Ichi Ueda (University of Toyama)
A network model for spatial control of arm movements

Lunch, 11:50-1:00

Free Discussion, 1:00-6:00

Banquet, 6:00

Session 7. Oct. 20, 9:00-10:00 Chair. Hisashi Okamoto

9:00-9:30, Shu Kanazawa (Tohoku University)
Asymptotic behavior of lifetime sums for random simplicial complex processes

9:30-10:00, Zhijian Yang (Wuhan University)
On the Cauchy-Born approximation: with finite temperature and with dilute defects

Coffee Break, 10:00-10:20

Session 7. Oct. 20, 10:20-11:50 Chair. Jaekyoung Kim

10:20-10:50, Eunok Jung (Konkuk University)
Dynamical models of tuberculosis transmission and optimal treatment strategies in the Republic of Korea and Philippines

10:50-11:20, Sungrim Seirin-Lee (Hiroshima University & JST PRESTO)
A Single Equation which Solved the Mystery of Urticaria

11:20-11:50, Masaaki Uesaka (Hokkaido University)
A variational problem arising from the modelling of epidermal basement membrane and its analysis

Lunch, 11:50-1:30

Session 9. Oct. 20, 1:30-3:00 Chair. Sung-Ik Sohn

1:30-2:00, Do Wan Kim (Inha University)
Optimal Arrangement of Photobioreactor Panels on Earth

2:00-2:30, Ruo Li (Peking University)
13-Moment System with Global Hyperbolicity for Quantum Gas

2:30-3:00, Yana Di (Chinese Academy of Sciences)
Anisotropic mesh and stabilization parameter for stabilized FEM

Coffee Break, 3:00-3:20

Session 10. Oct. 20, 3:20-4:20 Chair. Eunok Jung

3:20-3:50, Hui Zhang (Beijing Normal University)
Stabilized-IEQ approach for anisotropic Cahn-Hilliard Equation

3:50-4:20, Eun-Hee Park (Kangwon National University)
A non-overlapping DD solver for biharmonic problems

Coffee Break, 4:20-4:40

Session 11. Oct. 20, 4:40-5:40 Chair. Dowan Kim

4:40-5:10, Koya Sakakibara (Kyoto University & RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program)
Unified numerical scheme for several types of Hele-Shaw problems by the method of fundamental solutions

5:10-5:40, Xia Ji (Chinese Academy of Sciences)
Direct sampling methods for inverse elastic scattering problems

Dinner, 6:30

Abstracts

in alphabetical order of speaker's names

A mathematical model of collective cell migrations based on cell polarity

Masakazu Akiyama (Research Institute for Electronic Science, Hokkaido University)
Takamichi Sushida (Research Institute for Electronic Science, Hokkaido University)
Hitomi Mori (Graduate School of Life Science, Hokkaido University),
Sumire Ishida (Graduate School of Life Science, Hokkaido University)
Hisashi Haga (Faculty of Advanced Life Science, Hokkaido University)

Collective cell migration has been investigated as a self organization phenomenon in life activities. Recently, rotational phenomena of collective cell migrations observed in morphogenesis are focused. For example, they are observed in the elongation process of the fruiting body formation of *Dictyostelium Discoideum*. In contrast, in experiments using Madin-Darby canine kidney cells and cancer cells (a kind of epithelial cells), several migration modes which contain rotational migration are observed. Our goal is to extract essential mechanisms of collective cell migrations in morphogenesis from mathematical modeling. In this talk, we select the self-propelled particle method [1], propose a new model focusing on cell polarity, and explore mechanisms of which each migration mode occurs robustly for the parameters and the initial conditions. As a numerical result, we show a phase diagram for the parameters of a driving force by the cell polarity and the cell-cell adhesive force. In the phase diagram[2], migration modes are classified as follows:

(i) Rigid rotational migration,
(ii) Non-rigid rotational migration,
(iii) Switch rotational migration and
(iv) Uniformly directional migration.

(i), (ii), and (iv) are observed in known migration modes for some cell species. On the other hand, (iii) of which clockwise and counterclockwise rotational directions are repeated has not been observed as a typical migration mode. However, by changing cell culture environment referring to our numerical result, (iii) is observed in experiments using the esophageal cancer cells. This suggests that our model gives a standard framework for understanding collective cell migrations.

In zebrafish somite, it has been confirmed that the cell group elongates while rotating. By expanding the model showing the above motion modes to 3D model, we are also challenging this somite problem. In the lecture, I will also talk about mathematical approach to this problem.

References

[1] Camley, Brian A and Zimmermann, Juliane and Levine, Herbert and Rappel, Wouter-Jan. (2016). Collective signal processing in cluster chemotaxis: Roles of adaptation, amplification, and co-attraction in collective guidance, PLoS Comput Biol, volume 12, number 7, e1005008.

[2] M. Akiyama, T. Sushida, S. Ishida and H. Haga. (2017). Mathematical model of collective cell migrations based on cell polarity, Dev Growth Differ, Number of 2017, doi: 10.1111/dgd.12381.

Anisotropic mesh and stabilization parameter for stabilized FEM
Yana Di (Chinese Academy of Sciences)

We propose a numerical strategy to generate a sequence of anisotropicmeshes and select appropriate stabilization parameters simultaneously for linear SUPG method solving two dimensional convection-dominated convection-diffusion equations. Since the discretization error in a suitable norm can be bounded by the sum of interpolation error and its variants in different norms, we replace them by some terms which contain the Hessian matrix of the true solution, convective field, and the geometric properties such as directed edges and the area of triangles. Based on this observation, the shape, size and equidistribution requirements are used to derive corresponding metric tensor and stabilization parameters.

How to choose the best solution in the application of Onsager's variational principle
Masao Doi (Beihang University)

Onsager's variational principle has been shown to be quite useful in soft matter physics, in deriving the basic set of equations to be solved, and also in solving those equations. In this talk, I will show that the principle can be stated in a more convenient form for application: it can be stated in the form of minimal path principle that nature chooses the path that minimizes certain time integral of a modified Rayleighian. I will show that this formulation will open new applications of the Onsager principle to wider classes of problems. This work was motivated by a stimulating discussion with Prof. Hans Crirstian Ottinger (ETH, Zurich).

Direct sampling methods for inverse elastic scattering problems
Xia Ji (Chinese Academy of Sciences)

We consider the inverse elastic scattering of incident plane compressional and shear waves from the knowledge of the far field patterns. Specifically, three direct sampling methods for location and shape reconstruction are proposed using the different component of the far field patterns. Only inner products are involved in the computation, thus the novel sampling methods are very simple and fast to be implemented. With the help of the factorization of the far field operator, we give a lower bound of the proposed indicator functionals for sampling points inside the scatterers. While for the sampling points outside the scatterers, we show that the indicator functionals decay like the Bessel functions as the sampling point goes away from the boundary of the scatterers. We also show that the proposed indicator functionals continuously dependent on the far field patterns, which further implies that the novel sampling methods are extremely stable with respect to data error. For the case when

the observation directions are restricted into the limited aperture, we firstly introduce some data retrieval techniques to obtain those data that can not be measured directly and then use the proposed direct sampling methods for location and shape reconstructions. Finally, some numerical simulations in two dimensions are conducted with noisy data, and the results further verify the effectiveness and robustness of the proposed sampling methods, even for multiple multiscale cases and limited-aperture problems.

Dynamical models of tuberculosis transmission and optimal treatment strategies in the Republic of Korea and Philippines

Eunok Jung (Konkuk University)
Aurelio A. de los Reyes V (University of the Philippines Diliman)
Sunhwa Choi (National Cancer Center)
Soyoung Kim (Konkuk University)

In this talk, we will present several mathematical models of tuberculosis (TB) based on the reported data in the Republic of Korea and Philippines, and also propose the optimal treatment strategies depending on the various scenarios in each country. Korea has ranked the highest TB incidence among members of the Organization for Economic Cooperation and Development (OECD). TB is the sixth leading cause of morbidity and mortality in the Philippines. The least-square curve fitting have been used for beat fitting the parameters in our models to the observed data. To determine the optimal intervention strategy which is reducing the number of exposed and infectious individuals and the cost of control measures, optimal control theory was used. Important issues has been addressed from our research: implementing the smoking controls, not with TB controls, can derive significant reduction of the incidence of TB transmission. We suggested the rearrangement of the Korean government TB budget based on optimal treatment strategies from modeling. Finally, in the Philippines enhancing active finding control is a significant control factor to curtail the spread of TB.

Oscillatory motions of colloidal particles in an evaporating droplet containing surfactant

Narina Jung (Department of Mechanical Engineering, UNIST)
Hae Won Seo (Department of Mechanical Engineering, UNIST)
Chun Sang Yoo (Department of Mechanical Engineering, UNIST)

Evaporation of a drop induces an outward capillary flow, leaving a coffee-ring stains of colloidal particles at the edge. This pattern can be altered by the addition of surfactant, generating Marangoni flows. At the locations where the capillary flow and Marangoni flows compete in the opposite directions, intricate time-dependent motions of colloidal particles occurs. Here, we investigate the oscillatory dynamics of colloidal particles in a drying droplet using a coarse grained lattice model. When Marangoni flows at the contact line enter the dynamic competition with a capillary flow, the aggregation/depletion zones of particles is generated, creating additional Marangoni flows close to the droplet edge. We found the formation of the aggregation zone is the main cause of the temporal and spatial oscillatory motions of colloidal particles. Furthermore, the effects of surfactants on the related time

scales to generate/degenerate oscillatory flows are elucidated through the control of the relative strength of Marangoni flows. Finally, we compute time scales of the oscillation in the simulations, and compare them with the estimated values based on the transport rates of surfactants.

Asymptotic behavior of lifetime sums for random simplicial complex processes
Shu Kanazawa (Tohoku University)
Masanori Hino (Kyoto University)

Abstract: We study the homological properties of random simplicial complexes. In particular, we obtain the asymptotic behavior of lifetime sums for a class of increasing random simplicial complexes [4]; this result is a higher-dimensional counterpart of Frieze's $\zeta(3)$-limit theorem for the Erdős–Rényi graph process [2]. The main results include solutions to questions posed in an earlier study by Hiraoka and Shirai about the Linial–Meshulam complex process and the random clique complex process [5]. One of the key elements of the arguments is a new upper bound on the Betti numbers of general simplicial complexes in terms of the number of small eigenvalues of Laplacians on links. This bound can be regarded as a quantitative version of the cohomology vanishing theorem [1, 3].

References

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Spectral structure of the Neumann–Poincaré operator on tori
Daisuke Kawagoe (Inha University)

We show that the Neumann–Poincaré operator on a torus has not only infinitely many positive eigenvalues but also infinitely many negative ones. To this aim, we introduce the toroidal coordinate system and decompose the Neumann–Poincaré operator into infinitely many operators by applying the Fourier expansion with respect to the usual toroidal angle to its integral kernel. We estimate numerical ranges of obtained operators in order to discuss signs of their eigenvalues, which is related to the sign of the original Neumann–Poincaré operator. This is the first example of two-dimensional surfaces on which the Neumann–Poincaré

operator has infinitely many negative eigenvalues. This is a joint work with Kazunori Ando (Ehime), Yong-Gwan Ji (Inha), Hyeonbae Kang (Inha) and Yoshihisa Miyanishi (Osaka).

Optimal Arrangement of Photobioreactor Panels on Earth

Do Wan Kim* (Inha University, Mathematics, *Presenter)
Choul-Gyun Lee (Inha University, Biological Engineering)
Jin-Hee Yoon (Inha University, Physics)

Echo-friendly energy source has been always the light beams from the Sun. Micro-algae is one of micro-organisms that can be cultivated in fluids contained an array of transparent flat panels. This device is called a photobioreactor(PBR). When a prescribed location on Earth is given in terms of the latitude and longitude, an interest question arises. Which arrangement of the photobioreactor panels can be optimal? The objective for optimality should be defined in a dimensionless ratio between the total amount of input solar energy and the total cost for the PBR installation during a given period of time, one year in this paper. To do this, we have to make a computational model, based on physics, for the solar radiation energy onto Earth and the calculation of the solar position on Earth at any time as a dimension of day as well.

As a result, we obtain interesting results for the optimal arrangements at various places on Earth. East-West facing array of panels is almost optimal in low latitude regions whereas the South-North facing array is optimal in high latitude regions. There apparently occur a transient region in-between. The length of transient region depends on the area ratio and the cost ratio. In Korea, South facing house has been preferable compared to other directions. It comes from not only a traditional experience but also now the computational result. Moreover, we can calculate the optimal gap between panels in the PBR array. In fact, it turns out that the optimal gap should be determined by the multiple factor to the panel height. The optimal multiple factors calculated for the gap are distributed almost near 1. This is attributed to the combination of shade and illumination effects between panels.

Beyond the century of the Michaelis-Menten equation

Jaekyoung Kim (KAIST)

Examining enzyme kinetics is critical for understanding cellular systems and for using enzymes in industry. The Michaelis-Menten equation has been widely used for over a century to estimate the enzyme kinetic parameters. However, this canonical approach works in limited conditions, such as when there is a large excess of substrate over enzyme. To overcome such limitations of the canonical approach, here we use an equation derived with the total quasi-steady-state approximation. In contrast to the canonical approach, estimates obtained with this proposed approach exhibit little bias for any combination of enzyme and substrate concentration. Importantly, this new approach provides much more accurate estimation of drug clearance rate in human liver than the canonical approach.

The role of microenvironment in regulaNon of cell infiltraNon and bortezomib-OV therapy in glioblastoma

Yangjin Kim (Konkuk University)
Ji Young Yoo (University of Texas Health Science Center at Houston)
Tae Jin Lee (University of Texas Health Science Center at Houston)
Joseph Liu (Ohio State University Wexner Medical Center)
Jianhua Yu (Ohio State University Wexner Medical Center)
Michael A. Caligiuri (City of Hope National Medical Center)
Balveen Kaur (University of Texas Health Science Center at Houston)
Avner Friedman (Mathematical Biosciences Institute, OSU)

Oncolytic viruses such as herpes simplex virus-1 (oHSV) are genetically modified to target and kill cancer cells while not harming healthy normal cells and are currently under multiple clinical trials for safety and efficacy [1]. Bortezomib is a peptide-based proteasome inhibitor and is an FDA-approved drug for myeloma and mantle cell lymphoma. Yoo et al (2) have previously demonstrated that bortezomibinduced unfolded protein response (UPR) in many tumor cell lines (glioma, ovarian, and head and neck) up-regulated expression of heat shock protein 90 (HSP90), which then enhanced viral replication through promotion of nuclear localization of the viral polymerase in vitro. This led to synergistic tumor cell killing in vitro, and a combination treatment of mice with oHSV and bortezomib showed improved anti-tumor efficacy in vivo [2]. This combination therapy also increased the surface expression levels of NK cell activating markers and enhanced pro-inflammatory cytokine secretion. These findings demonstrated that the synergistic interaction between oHSV and bortezomib, a clinically relevant proteasome inhibitor, augments the cancer cell killing and promotes overall therapeutic efficacy. Therefore, there is a sound ground for combining these agents in a clinical trial. In the present paper we investigated the role of NK cells in combination therapy with oncolytic virus (OV) and bortezomib. NK cells display rapid and potent immunity to metastasis and hematological cancers, and they overcome immunosuppressive effects of tumor microenvironment. We developed a mathematical model, a system of PDEs, in order to address the question of how the density of NK cells affects the growth of the tumor [3]. We found that the anti-tumor efficacy increases when the endogenous NKs are depleted, and also when exogenous NK cells are injected into the tumor. These predictions were validated by our in vivo and in vitro experiments.

References

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[2] Yoo J, et al., "Bortezomib-induced unfolded protein response increases oncolytic hsv-1 replication resulting in synergistic antitumor effect", *Clin Cancer Res* , Vol. 20(14), 2014, pp. 3787-3798.

[3] Yangjin Kim, Ji Young Yoo, Tae Jin Lee, Joseph Liu, Jianhua Yu, Michael A. Caligiuri, Balveen Kaur and Avner Friedman, "Complex role of NK cells in regulation of oncolytic virus-bortezomib therapy", *PNAS*, May 8, 2018, 115 (19), pp. 4927-4932.

13-Moment System with Global Hyperbolicity for Quantum Gas
Ruo Li (Peking University)

We point out that the quantum Grad's 13-moment system given by Yano is lack of global hyperbolicity, and even worse, the thermodynamic equilibrium is not an interior point of the hyperbolicity region of the system. To remedy this problem, we split Grad's expansion into the equilibrium part and the non-equilibrium part, and propose a regularization for the system. This provides us a new model which is hyperbolic for all admissible thermodynamic states, and meanwhile preserves the approximate accuracy of the original system. It should be noted that this procedure is not a trivial application of the theory we developed in 2015.

On the construction of weakly neutral inclusions
Xiaofei Li (Zhejiang University of Technology)

Upon insertion of an inclusion into a medium with the uniform field, if the field is not perturbed at all outside the inclusion, then it is called a neutral inclusion. It is called a weakly neutral inclusion if the field is perturbed weakly. Neutral and weakly neutral inclusions have significant implications in the theory of composites, imaging and invisibility cloaking. A two dimensional inclusion of core-shell structure is neutral to multiple uniform fields if and only if the core and the shell are concentric disks, provided that the conductivity of the matrix is isotropic. We show, by an implicit function theorem, that if the core is a small perturbation of a disk then we can coat it by a shell so that the resulting structure becomes weakly neutral to multiple uniform fields. For construction weakly neutral inclusions of general shape, we show that a simply connected domain satisfying a certain geometric condition can be realized as a weakly neutral inclusion to multiple fields by introducing an imperfect interface parameter on the boundary. The geometric condition on the domain and the imperfect interface parameter are determined by the first coefficient of the conformal mapping from the exterior of the unit disk onto the exterior of the domain. We provide some numerical examples to compare field perturbations by weakly neutral inclusions and perfectly bonding interfaces. They clearly show that the field perturbation by weakly neutral inclusions is much weaker. This talk is based on joint works with Hyeonbae Kang (Inha University) and Shigeru Sakaguchi (Tohoku University)

Percolation on homology generators in codimension 1
Tatsuya Mikami (Tohoku University)
Yasuaki Hiraoka (Kyoto University)

Percolation theory is a branch of probability theory which describes the behavior of clusters in a random graph, and it has many applications to material science such as immersion in a porous stone. Recently, craze formation in polymer materials is gaining attention as a new type of percolation phenomenon. A large void corresponding to a craze of the polymer starts to appear by the process of coalescence of many small voids, which suggests that "percolation of nanovoids" is the key mechanism to initiate craze formation.

In this study, we introduce a new percolation model motivated from the craze formation of polymer materials. For the sake of modeling the coalescence of nanovoids, our model focuses on clusters of holes in $\mathbb{R}^d$ as higher dimensional topological objects, while the classical percolation theory mainly studies clusters of vertices (i.e., 0-dimensional objects). More precisely, we use homology generators in dimension $d-1$ for representing the holes and then study infinite clusters of those holes.

Theoretical analysis of a mathematical model for a self-propelled motion

Masaharu Nagayama (Hokkaido University)
Mamoru Okamoto (Hokkaido University)
Yusuke Yasugahira (Hokkaido University)
Takeshi Gotoda (Hokkaido University)
Hiroyuki Kitahata (Chiba University)
Satoshi Nakata (Hiroshima University)

Mathematical modelling can not only be used to clarify the mechanism of characteristic features of self-propelled motion, but also to design an original self-propelled system. In this talk, we explain how spatio-temporal features of self-propelled motion can be reproduced by a mathematical model. The model is composed of a reaction-diffusion equation for camphor molecule layer on water surface, and a equation of motion for a self-propelled object. We next treat the existence and stability of a constant velocity solution of the mathematical model, and finally report the motion of multiple self-propelled objects using a numerical simulation and a mathematical analysis.

Numerical computation of water waves on two vortical layers

Hisashi Okamoto (Gakushuin University)
Mayumi Shōji (Japan Women's University)

Stationary waves of constant shape and propagation speed on rotational flow of two layers are computed numerically. Two layers are assumed to be of distinct constant vorticity distributions. Three different kinds of waves of finite depth are considered: pure capillary, capillary-gravity, and gravity waves. This is a bifurcation problem of a complicated structure of solutions with many parameters. We will adopt a numerical method by which waves with stagnation point(s) can be computed, obtaining variety of new solutions. It is also reported that the places where the stagnation points appear varies with the given parameters and they offer an interesting challenge.

A non-overlapping DD solver for biharmonic problems

Eun-Hee Park (Kangwon National University)

In this talk we will discuss a non-overlapping domain decomposition (DD) solver for biharmonic problems. There are two key ingredients in the proposed DD solver: one is a subspace decomposition of the finite element space and the other is a procedure based on balancing domain decomposition by constraints. The performance of DD solvers are mainly

determined by the condition number of the resulting linear system. Theoretical results on the condition number estimate of the system will be presented along with numerical results. The is a joint work with Susanne C. Brenner, Li-yeng Sung and Kening Wang.

Some properties of Liquid Crystals
Jinhae Park(Chungnam National University)

Recently, Liquid crystal has been one of the popular research areas due to its application and many mathematical challenges. Structures of liquid crystals are complex due to the contributions of twist, bending and splay moduli appearing in the energy. In smectic liquid crystals, liquid crystals rotates with a fixed angle with layers which produce a pattern of singular points. In this talk, we study some properties of liquid crystals about singularities in smectic liquid crystals in 2D.

Unified numerical scheme for several types of Hele-Shaw problems by the method of fundamental solutions
Koya Sakakibara (Department of Mathematics, Kyoto University & RIKEN Interdisciplinary Theoretical and Mathematical Sciences Program)
Shigetoshi Yazaki (Department of Mathematics, Meiji University)

The classical Hele-Shaw problem describes a motion of fluids sandwiched between two parallel plates with a narrow gap, and it has been studied by many researchers as a fundamental model of viscous fingering phenomena. In this talk, we first establish a structure-preserving numerical scheme for the classical Hele-Shaw problem and show some mathematical results. We next apply our numerical scheme to several problems such as the Hele-Shaw problem with a time-dependent gap, and stabilization of the backward mean curvature flow. We verify the effectiveness of our numerical scheme through numerical experiments.

A Single Equation which Solved the Mystery of Urticaria
Sungrim Seirin-Lee (Department of Mathematics, Hiroshima University & JST PRESTO)
Michihiro Hide (Department of Dermatology, Hiroshima University)

Skin develops various eruptions unique to disease entities or individuals in shape, size, color and/or texture of the skin surface. However, most of such visible characteristics cannot be explained by characteristics of individual molecules or cells which are diffusely distributed in the skin in microscopic level. Here we revealed that a simple mathematical structure may explain multifarious eruptions of urticaria, a common skin disorder characterized by rapid appearance and disappearance of local skin edema and flare with itching. Using this model, we succeeded in regenerating many multifarious urticaria eruptions observed on real patients with urticaria.This study may help not only understanding the pathogenesis of urticaria, but also opening an entirely new trail of a mathematical approach to analyze various skin diseases with geometric eruptions and predict the effectiveness of treatments in dry labs.

A network model for spatial control of arm movements
Kei-Ichi Ueda (Graduate School of Science and Engineering, University of Toyama)

We propose a network model for boundary value problems and apply the system to arm-reaching problems. The node dynamics is described by a FitzHugh-Nagumo-like model. Nodes correspond to the n-th joint are located on the n-th square matrix. The position of each joint is represented by the position of the node in an on-state in the corresponding matrix. The system also has self-recovery property, that is, the system spontaneously finds a new solution when the boundary condition is abruptly changed.

A variational problem arising from the modelling of epidermal basement membrane and its analysis
Masaaki Uesaka (Hokkaido University)
Yasuaki Kobayashi (Ochanomizu University)
Masaharu Nagayama (Hokkaido University)
Ken-ichi Nakamura (Kanazawa University)
Keiichi Ueda (Toyama University)

In this talk, we consider the following variational problem for a curve γ in 2-dimensional space:

$$E[\gamma] = \int_0^{L_\gamma} \varepsilon_{\mathrm{e}}^2 \kappa^2 \,\mathrm{d}s + \int_0^{L_\gamma} \frac{\varepsilon_{\mathrm{a}}(s)}{2} \kappa(s) \,\mathrm{d}s,$$

where L_γ is a length of γ, the variable s is the arc-length parameter and κ is the signed curvature of γ. ε_{e} is a constant and $\varepsilon_{\mathrm{a}}(s)$ is positive and non-constant. The characteristic properties of this energy are that the linear term with respect to the curvature is introduced and that the coefficient $\varepsilon_{\mathrm{a}}(s)$ is non-uniform along the curve. These two properties are derived from the modelling of the epidermal basement membrane, which splits the dermis and the epidermis in skin structure, and the linear term in κ with non-uniform coefficient comes from the adhesion of the proliferating cells on the membrane. We will talk on this relationship and the result on stationary points of $E[\gamma]$ described by graph of a piecewise smooth function. Especially, We will show that the stationary points of $E[\gamma]$ may overhang if the amplitude of ε_{a} is large, which suggests the generation of the protuberance, called dermal papillae, of the epidermal basement membrane.

Efficient Numerical Methods for the Inextensible Immersed Interface in Incompressible Flows
Chuanju Xu (Xiamen University)

In this talk, we investigate the equation governing the movement of an immersed interface in incompressible fluid flows, and propose efficient methods for its numerical solutions. The particularity of the model is the inextensibility constraint imposed on the interface. We are interested in constructing suitable variational formulations associated to this problem and the well-posedness of the weak problem. The significance of this variational formulation is that both the inextensibility of the interface and fluid incompressibility are strictly satisfied, so that well-posedness of the associated weak problem can be rigorously established. Then,

based on the proposed variational framework, we design efficient methods for numerical approximations to the weak solution, together with a detailed stability analysis.

On the Cauchy-Born approximation: with finite temperature and with dilute defects
Zhijian Yang (Wuhan University)

Constitutive relation is a fundamental material property and plays important roles in the study of materials. It comes with a multiscale nature. Either experiments or massive simulations are needed to get such material properties, which both are very expensive. In this talk, I will introduce our recent work on the efforts of effectively evaluating material constitutive relations. It can be considered as generalization of traditional Cauchy-Born approximation, which bridges different models at atomistic and continuum level and only works for perfect system at zero-temperature. I will talk about our recent results on modeling, simulation as well as analysis.

Surface plasmons of geometrically singular structures
Sanghyeon Yu (ETH)

Confining light into a nanoscale region is quite challenging due to the diffraction limit. To overcome this difficulty, the plasmonic (metallic) nanoparticles and their optical resonances (surface plasmons) have been extensively studied and utilized.Among various plasmonic structures, geometrically singular structures such as touching surfaces and sharp corners are of the fundamental importance since they exhibit the broadband light concentration. This phenomenon has a potential application in nanophotonics,biosensing and spectroscopy. We shall discuss the mathematical aspects of the surface plasmons of geometrically singular structures.

Stabilized-IEQ approach for anisotropic Cahn-Hilliard Equation
Hui Zhang (Beijing Normal University)

In this talk, we report the numerical approximations for the sixth order and highly nonlinear anisotropic Cahn-Hilliard equation. The challenges in solving such a diffusive system numerically are how to develop proper temporal discretization for nonlinear terms in order to preserve the energy stability at the time-discrete level, and especially how to deal with the strong anisotropic term. We solve these issues by developing a set of the first and second order time marching schemes based on a novel, called "Invariant Energy Quadratization" approach and the stabilization method, which is the critical point. Its novelty is that all nonlinear terms are treated semi-explicitly to produce linear schemes. These linear schemes are efficiently solved by using a spectral-Galerkin method and PCG. Also, the stabilizing terms added here can suppress the non-physical oscillations efficiently, which are caused by the strong anisotropic nonlinear derivative terms. All the 1st- and 2nd- order schemes are proved to be unconditionally energy stable and well-posed rigorously. Various numerical simulations, including the linear bi-Laplacian regularization and the nonlinear Willmore

regularization, are presented to demonstrate the stability, accuracy and efficiency of the proposed schemes thereafter. The numerical results with $2D$ and $3D$ cases are consistent with earlier work on this topic, and various simulations.

Solution landscapes of Nematic Liquid Crystal
Lei Zhang (Beijing International Center for Mathematical Research, Peking University)

Topological defect plays an important role in the physics of liquid crystals. Although a large amount of previous studies is devoted to understand and compute the stable defect structures in liquid crystals as a consequence of geometric frustration, less attention has been paid to investigate the transition states between stable defect structures and the solution landscapes of nematic liquid crystals. In this talk, we first show that a combination of the Landau-de Gennes model and the multi-scale string method can systematically investigate the transition pathways between different defect patterns of nematic liquid crystals confined in a 3D cylinder with homeotropic boundary condition in 3D cylinder. Next, we proposed a High index Optimization-based Shrinking Dimer (HiOSD) method to compute the complete defect landscape of Nematic Liquid Crystals in 2D square. The joint work with Pingwen Zhang (PKU), Yucheng Hu (Tsinghua).

A weak Galerkin finite element scheme for the Cahn-Hilliard equation
Ran Zhang (Jilin University)

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

Poster Presentation

Qing Cheng (Xiamen U.)
A efficient numerical scheme for coupled cahn-hilliard equations

Yong-Gwan Ji (Inha U.)
A concavity condition for existence of a negative Neumann-Poincare eigenvalue in three dimensions

Junhong Jo (Inha U.)
Axial Green function Method with Arbitrary Refinement

Hyundong Kim (Korea U.)
Comparison study on the different dynamics between the Allen-Cahn and Cahn-Hilliard eqautions

Soyoung Kim (Konkuk U.)
Mathematical Model and Intervention Strategies for Tuberculosis Transmission in the Philippines

Youngsuk Ko (Konkuk U.)
Mathematical Model of Highly Pathogenic Avian Influenza and Analysis of Optimal Culling Radius Decision in the Republic of Korea

Donggu Lee (Konkuk U.)
Role of N1/N2 neutrophils in regulation of tumor growth in lung cancer

Junho Lee (Konkuk U.)
Intracellular regulation of massive cell death in Bortezomib-OV therapy

Tomohiro Nakahara (Hiroshima U.)
The role of cytoplasmic proteins on cell polarity formation of asymmetric cell division

Masaaki Nomata (Hiroshima U.)
Modeling and optimal policy for decreasing Japanese empty homes, Akiya, due to an aging society

Jianyuan Yin (Peking U.)
High index optimization-based shrinking dimer method for high index saddle points

Sung Sic Yoo (Inha U.)
Novel Approach for 2-Dimensional Impinging jets

Bing Yu (Peking U.)
Global optimization-based dimer method for finding saddle points

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