[Mathematical Modeling & Scientific Computing]

Lin, Wen-Wei
Lai, Ming-Chih
Yeh, Li-Ming
Lee, Yuh-Jye
Wu, Chin-Tien
Chang, Shu-Ming
Shiue, Ming-Cheng
Lin, Te-Sheng

[Financial Engineering & Probability]

Sheu, Yuan-Chung
Chen, Guan-Yu

[Differential Equations & Dynamical Systems]

Lin, Song-Sun
Jonq, Juang
Shih, Chih-Wen
Li, Ming-Chia
Lee, Jong-Eao
Huang, Hsin-Yuan
Yu, Chi-Jer

[Discrete Mathematics & Optimization]

Weng, Chih-Wen
Chen, Chiu-Yuan
Fu, Hung-Lin
Fuchs, Michael
Lin, Wu-Hsiung

[Number Theory, Geometry & Analysis]

Wang, Shiah-Sen
Hsu, Yi-Jung
Wang, Kuo-Zhong
Kang, Ming-Hsuan
Chan, Chi-Hin
Spector, Daniel E.

Undergraduate Program	236
3 Master Programs	90
3 PhD Programs	30

Faculty 師資人員

- Faculty
- Visitors
- Postdocs
- Ph.D. Students
- Staff

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Cross-Disciplinary

Faculty and Research Area

---- Faculty and Research Areas ----

Chair Professors

Title: National Chair-Professor, Ministry of Education

Name: Song-Sun Lin

Email: sslin@math.nctu.edu.tw

Background: Ph. D. in Mathematics, Heriot-Watt Univ.

Specialties: Dynamical Systems, Analysis, Differential Equations

Office: SA 245 ext. 56425

Title: Chair Professor and Chair

Name: Wen-Wei Lin

Email: wwlin@math.nctu.edu.tw

Background: Ph.D., University of Bielefeld, Germany

Specialties: Numerical Analysis, Matrix Theory and Computations, Dynamical Systems, Optimal Control

Office: SA 201 ext. 56429

Title: Chair Professor

Name: Ming-Chih Lai

Email: mclai@math.nctu.edu.tw

Background: Ph. D. in Mathematics, Courant Institute, NYU

Specialties: Scientific Computing, Numerical Methods for PDEs, Mathematical Modeling, Fluid mechanics, Biophysics

Office: SA 243 ext. 31361

http://www.math.nctu.edu.tw/faculty/e_index.php

Distinguished Professor

Title: Distinguished Professor

Name: Juang Jonq

Email: jjuang@math.nctu.edu.tw

Background: Ph. D. in Applied Mathematics, Texas Tech Univ.

Specialties: Dynamical Systems, Differential Equations

Office: SA 346 ext. 31208

Full-Time Faculty

Title: Professor

Name: Chih-Wen Weng

Email: weng@math.nctu.edu.tw

Background: Ph. D. in Mathematics, Univ. of Wisconsin-Madison

Specialties: Algebraic Combinatorics

Office: SA 350 ext. 31610

Title: Professor

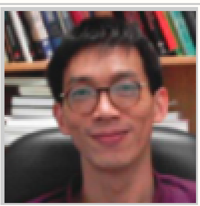
Name: Chih-Wen Shih

Email: cwshih@math.nctu.edu.tw

Background: Ph.D. in Mathematics, SUNY at Buffalo

Specialties: Differential equations, Dynamical systems, Neural networks, Mathematical biology

Office: SA 347 ext. 56409



Title: Professor

Name: Ming-Chia Li

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Background: Ph. D. in Mathematics, Northwestern Univ.

Specialties: Dynamical Systems, Differential Equations

Office: SA 337 ext. 56463

Title: Professor

Name: Yuan-Chung Sheu

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Background: Ph. D. in Mathematics, Cornell Univ.

Specialties: Probability Theory, Stochastic Processes

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Title: Professor

Name: Chiuyuan Chen

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Background: Ph. D. in Computer Engineering, National Chiao Tung Univ.

Specialties: Computer Algorithms, Graph Theory, The Application of Graph Theory to Interconnection Networks and Wireless Networks

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Title: Professor

Name: Li-Ming Yeh

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Background: Ph. D. in Mathematics, Purdue Univ.

Specialties: Numerical Analysis, Partial Differential Equations

Office: SA 339 ext. 56439

Title: Professor

Name: Hung-Lin Fu

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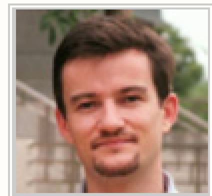
Background: Ph. D. in Mathematics, Auburn Univ.

Specialties: Graph Theory, Combinatorial Designs, Group Testing, Coding and Cryptography, Computational Molecular Biology, Archery

Office: SA 200 ext. 31623



Title: Professor

Name: Michael Fuchs

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Background: Ph. D. in Mathematics, Vienna Univ. of Technology

Specialties: Analytic Combinatorics, (Probabilistic) Analysis of Algorithms, Metric Number Theory

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Title: Professor and Vice Dean of College of Science

Name: Yuh-Jye Lee

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Background: Ph.D. in Computer Sciences, University of Wisconsin at Madison, USA

Specialties: Big Data & Data Science Data Mining Machine Learning Numerical Optimization Operations Research Information Security

Office: SA240

Title: Associate Professor

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Background: Ph. D. in Mathematics, Rice Univ.

Specialties: Variational Calculus, Geometric Measure Theory

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Title: Associate Professor

Name: Jong-Eao Lee

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Background: Ph. D. in Mathematics, Ohio State Univ.

Specialties: Partial Differential Equations

Office: SA 236 ext. 56412, 31304

Title: Associate Professor

Name: Yi-Jung Hsu

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Background: Ph. D. in Mathematics, National Tsing Hua Univ.

Specialties: Differential Geometry

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Title: Associate Professor and Director of CMMSC Master Program

Name: Chin-Tien Wu

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Background: Ph.D. Applied Mathematics and Scientific Computation,University of Maryland, College Park, USA.

Specialties: Scientific Computation, Fluid Mechanics

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Title: Associate Professor

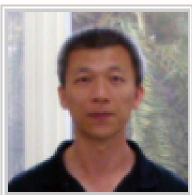
Name: Guan-Yu Chen

Email: gychen@math.nctu.edu.tw

Background: Ph. D. in Mathematics, Cornell Univ.

Specialties: Probability Theory, Stochastic Processes

Office: SA 343 ext. 56421



Title: Associate Professor

Name: Shu-Ming Chang

Email: smchang@math.nctu.edu.tw

Background: Ph. D. in Mathematics, National Tsing Hua University

Specialties: Scientific Computations, Dynamical Systems

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Title: Associate Professor

Name: Kuo-Zhong Wang

Email: kzwang@math.nctu.edu.tw

Background: Ph. D. in Mathematics, National Tsing Hua Univ.

Specialties: Inequalities, Functional Analysis, Matrix Analysis

Office: SA 237 ext. 56483

Title: Associate Professor

Name: Ming-Hsuan Kang

Email: mhkang@math.nctu.edu.tw

Background: Ph.D. in Mathematics, The Pennsylvania State University

Specialties: Number Theory and Its Applications

Office: SA 230 ext. 56416

Title: Associate Professor

Name: Ming-Cheng Shiue

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Background: Ph.D. in Mathematics, Indiana Univ.

Specialties: Numerical Analysis and Geophysical Fluid Dynamics

Office: SA 226 ext. 56406

Title: Associate Professor

Name: Chi-Hin Chan

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Background: Ph.D. in Mathematics, University of Texas at Austin

Specialties: 1) Regularity estimates for elliptic and parabolic P.D.E's. 2) Studies of elliptic and parabolic equations on Riemannian manifolds. 3) P.D.E.'s arising from a fluid dynamics. 4) Study of geometric, topological, and analytical properties of solutions to Navier-Stokes equation on a Riemannian manifold.

Office: SA 229 ext. 56464

Title: Associate Professor

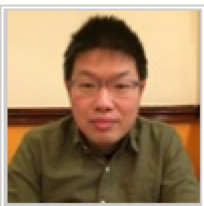
Name: Hsin-Yuan Huang

Email: hyhuang@math.nctu.edu.tw

Background: Ph.D. in Mathematics, University of Minnesota

Specialties: Mathematical Physics and Nonlinear Partial Differential Equations

Office: SA 238 ext. 56440



Title: Assistent Professor

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Email: tslin@math.nctu.edu.tw

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Specialties: Mathematical modeling, Scientific computing, Fluid mechanics

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Title: Assistant Professor

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Email: dspector@math.nctu.edu.tw

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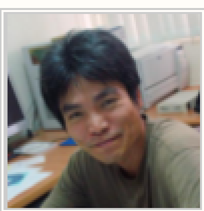
Specialties: Calculus of Variations, Geometric Measure Theory, PDE

Office: SA 239 ext. 56446



Title: Assistant Professor

Name: Chi-Jer Yu

Email: ycj@math.nctu.edu.tw

Background: Ph. D. in Applied Mathematics, National Chiao Tung University

Specialties: Differential Equations, Scientific Computation

Office: SA 340 ext. 31361

Title: Assistant Professor

Name: Wu-Hsiung Lin

Email: wuhsiunglin@nctu.edu.tw

Background: Ph.D in Mathematics, National Taiwan University

Specialties: Graph Theory

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Extension: 56425 Email: sslin@math.nctu.edu.tw

Prof. Song-Sun Lin / Department of Applied Mathematics

Dynamic system, Zeta function

My research areas are multi-dimensional symbolic dynamic systems and dynamic Zeta function.

1. Multi-dimensional symbolic dynamic system. Study the patterns generation problems on the plane. Set up the rectangular lattices on plane. Given a set of admissible local patterns and extend the patterns to global patterns on plane. The basic problems are:

    (i)Is there any global pattern on plane for a given set of admissible local patterns?
    (ii)How many global patterns? For example, is the growth of number of global pattern exponentially with respect to the size of lattices?
    (i.e. spatial chaos occurs?)
    (iii)How to compute the spatial entropy?
    (iv)Is there any nature measure to describe the patterns generation problem?
    (v)The probability to associate the local patterns which are located on different sites of plane. When the association is mixing or strong mixing?

2. Dynamic Zeta function:

Pick up the periodic patterns of the patterns generation problem to formulate a Zeta function. The Zeta function is an infinite product of rational functions, a meromorphic function on complex plane. The basic problems are:

    (i)The relation between the spatial entropy and natural boundary of Zeta function.
    (ii)The possible application of dynamic Zeta function to algebra or number theory.

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Prof. Wen-Wei Lin / Department of Applied Mathematics

Numerical Analysis, Matrix Theory and Computation, Optimization, Computational Conformal Geometry

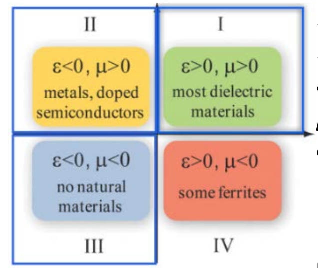
We are a research group on "Numerical Algebra and Geometry" in the ST Yau Center and Applied Math Department , NCTU. Our primary research interests include the following two parts:

(a) Eigendecomposition and Fast Eigensolver for 3D Maxwell's equations. We use finite difference Yee's scheme to discretize the Maxwell's equations with simple cube (SC) or face-centered cube (FCC) periodic domain into generalized or rational eigenvalue problems. We explicitly derive the eigendecomposition of the double-curl operator and SVD of the single curl operator. Then we develop a FFT-based algorithm for compact representations of $\nabla\times\nabla\times$ and $\nabla\times$ operators and propose null-space free methods with Newton-type and nonequivalence deflation technique for solving Maxwell's equations. We compute the band structures of (I) Dielectric materials, where $\varepsilon > 0, \mu > 0, \xi = \zeta = 0$; (II) Dispersive metallic photonic crystals with Drude or Drude-Lorentz models, where the permittivity $\varepsilon = \varepsilon(\omega)$ depends on the high-frequency ω with some poles; (III) Left-handed materials or negative-index material (complex media), where $\varepsilon < 0, \mu < 0, \xi, \zeta \neq 0$ are chiral or pseudo-chiral parameters. All trivial zero eigenvalues caused by the degenerate curl operator have been successfully deflated in our fast eigensolvers. FFT-based fast eigensolvers in Matlab code are developed to compute various band structures of I, II and III efficiently, reliably and robustly.

(b) 3D Computational conformal geometry with applications. We mainly develop efficient numerical methods to compute conformal mappings of 3D surfaces such as a genus zero closed surface, a simply connected surface with a single boundary and a closed surface of genus ≥ 1 conformally to a sphere S^2, a unit disk D_1, a parallelogram on R^2 $(g = 1)$ and a polygon domain on $H^2 (g \geq 2)$. We propose a Quasi-Implicit Euler Method to a nonlinear heat equation, and the discrete Ricci flow with circle packing technique on the closed surface of $g \geq 1$ to compute the associated conformal maps (Figure 1 and 2). A high-resolution 3D dynamical scanner equipped in the Lab of ST Yau Center can be used to capture various 3D human faces and the corresponding conformal disks (Figure 3). We actively cooperate with industry and develop the related applications in 3D animation, retargeting/driving with texture mapping (Figure 4 and 5). Furthermore, facial expression analysis, face recognition, antiquities presentation, industrial inspection, and medical image are under investigation.

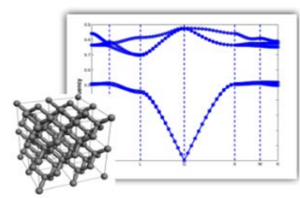
Maxwell's equations *Frequency Domain*

$$\nabla\times E = i\omega(\mu H + \zeta E),$$
$$\nabla\times H = -i\omega(\varepsilon E + \xi H),$$
$$\nabla\cdot(\varepsilon E) = 0, \nabla\cdot(\mu H) = 0.$$

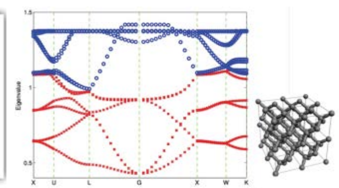


E: electronic filed,
H: magnetic filed,
ε: permittivity,
μ: permeability,
ζ, ξ: magnetoelectric parameters

I. Dielectric materials



II. Dispersive metallic materials



III. Negative index materials

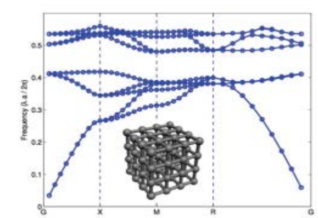


Figure 1

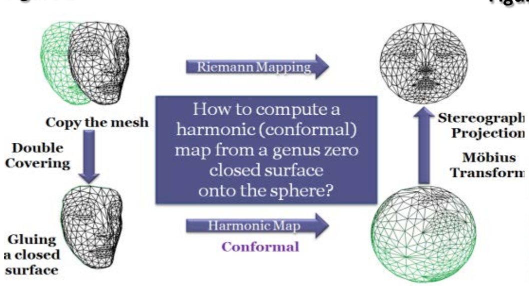


Figure 2

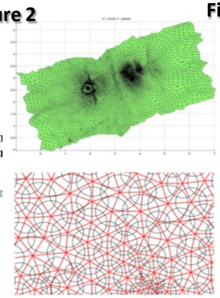


Figure 3

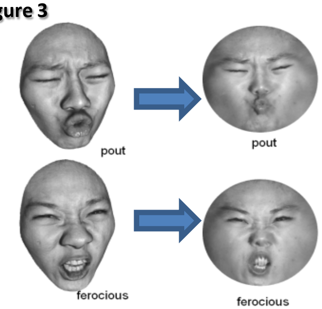


Figure 4

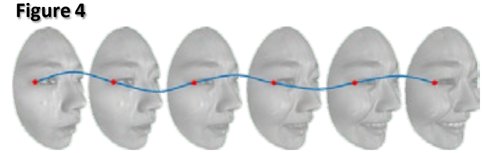


Figure 5

ST Yau Center

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Prof. Ming-Chih Lai / Department of Applied Mathematics

Numerical methods for PDEs, Complex fluid dynamics simulations

The study of the incompressible flows with interfaces is of major interests among applied mathematics community. It plays an important role in numerous natural phenomena and industrial applications, especially, for the soft matter physics and hydrodynamics of micro-fluidic systems. We have successfully developed simple and efficient numerical schemes based on immersed boundary method for simulating fluid-surfactant and fluid-vesicle dynamics. Brief descriptions are as follows.

(I) **Interfacial flows with insoluble/soluble surfactant.** Surfactant are surface active agents that adhere to the fluid interface and affect the interface surface tension. Surfactant play an important role in many applications in the industries of food, cosmetics, oil, water purification , etc. In microsystems with the presence of interfaces, it is extremely important to consider the effect of surfactant since in such cases the capillary effect dominates the inertia of the fluids. We demonstrate the equilibrium for a hydrophobic drop with clean (dashed line) and contaminated interface (solid line) in Figure 1; the concentration distribution of a soluble droplet imposed to a flow is shown in Figure 2.

(II) **Vesicle hydrodynamics.** Vesicles dynamics in fluid flow has become a quite active research area recently in the communities of soft matter physics and computational fluid mechanics. Indeed, the understanding of vesicle behaviors in fluids might lead to a better knowledge of red blood cells in bloods since they both share some similar mechanical behaviors. It is well-known that the phospholipid membrane exhibits a resistance against area dilation and bending; therefore, it is natural to regard this membrane as an inextensible surface with mechanical properties defined by some energy functional. We have proposed a series of immersed boundary methods to simulate the dynamics of two- and three-dimensional inextensible vesicles in Navier–Stokes flows; for demonstration, the snapshots of a freely suspended vesicle in quiescent flow are shown in Figure 3.

http://www.math.nctu.edu.tw/~mclai

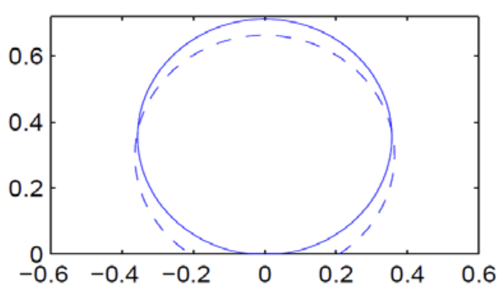

Figure 1

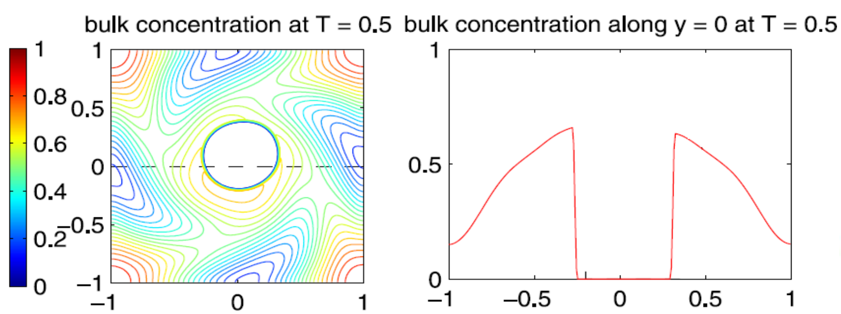

Figure 2

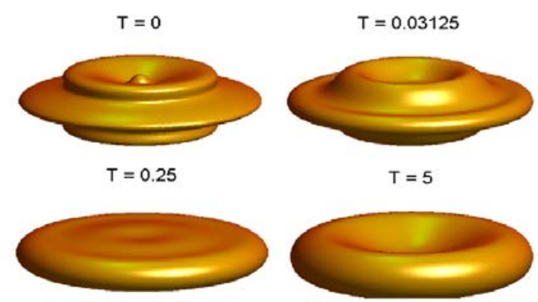

Figure 3

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Prof. Jonq Juang / Department of Applied Mathematics

Coupled Systems, Synchronization, Neural Networks, Neuronal Dynamics, Flocking Problems and Traffic Flow Models

Our research interests are centered around the real world problems that can be modeled by coupled networks. Among the problems under considerations are as follows: **(i) Coupled chaotic oscillators; Coupled maps lattices.** Our group has been studying synchronization phenomena in coupled systems for the last few years. We develop some analytical theorems to ensure the emerge of synchronization. These results can be applied to the realistic design of electronic circuit system and secure communication (Figure 1). **(ii) Biological neural networks; Neural pathways:** In the last few decades, the study of the neuronal dynamical behaviors has shifted to a network of neurons from a single neuron. Our group focuses on the study of synchronization phenomena in the neural network and probes the distinct neuronal dynamical behaviors under coupled neural networks (Figure 2). **(iii) Flocking behavior; Collective animal behavior exhibited by many living beings such as birds, fish, bacteria and insects:** Recently, we consider the flocking behaviors of living beings and discuss the mechanism of avoiding collision between them (Figure 3). **(iv) Epidemic models; Disease transmission models :** We are also interested in considering the impact of the individual contact networks, awareness and vectors on the disease spreading. **(v) Microscopic and macroscopic traffic flow models :** The traffic flow problem is one of our research interests. We wish to study some well-known traffic models to explain the traffic flow and the occur of traffic jams. In the future, we aim to use our model to predict and control the traffic flow in freeways of Taiwan.

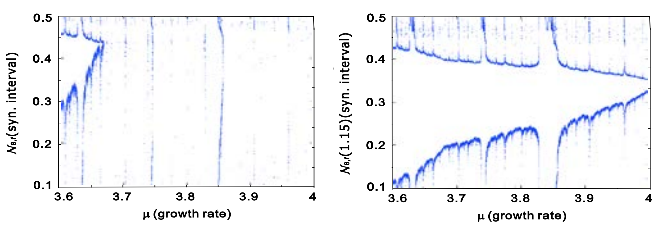

Figure 1: The wavelet transform method on the logistic map to increase the interval of synchronization.

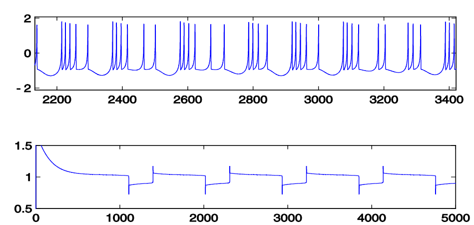

Figure 2: Neuron exhibits different firing dynamics without or with coupling.

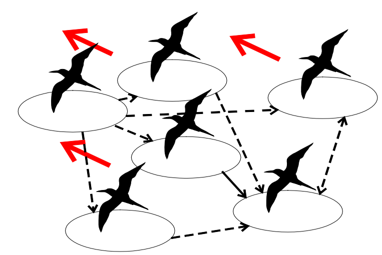

Figure 3: A flock of birds reaching the consensus fly with the same velocity and preserve their flying formation.

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Prof. Chih-wen Weng / Department of Applied Mathematics

Distance-Regular Graphs, Group Testings, Presentation and Representation Theory, Combinatorial Matrix Theory, Graph Theory

- Yu-pei Huang, Yeh-jong Pan and Chih-wen Weng, Nonexistence of a Class of Distance-Regular Graphs, the electronic journal of combinatorics, Volume 22, Issue 2 (2015), #P2.37

  (Show the nonexistence of a class of DRG)

- Jun Guo, Kaishun Wang, Chih-wen Weng, Pooling semilattices and non-adaptive pooling designs, Discrete Mathematics 320(2014), 64-72

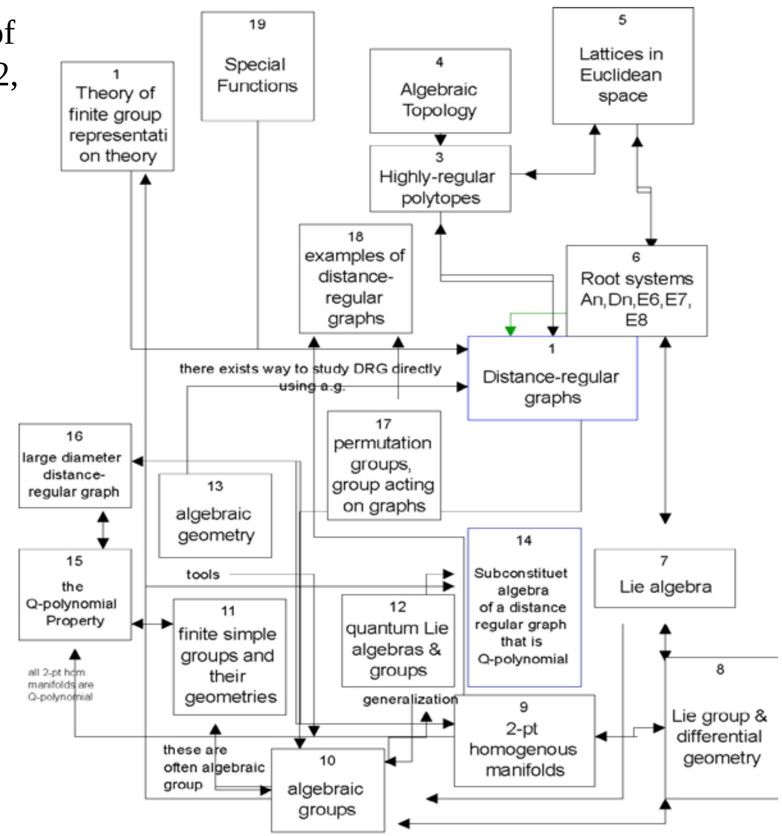
  (Construct pooling designs from semilattices)

- Chia-an Liu, Chih-wen Weng, Spectral radius of bipartite graphs, Linear Algebra and its Applications, 474(2015), 30–43

  (Provide a sharp upper bound of bipartite graphs)

- Yen-Jen Cheng, Feng-lei Fan, Chih-wen Weng, An extending result on spectral radius of bipartite graphs, arXiv:1509.07586

  (Provide a spectral characterization of twin primes)



Drew by Paul Terwilliger

http://jupiter.math.nctu.edu.tw/~weng/weng.htm

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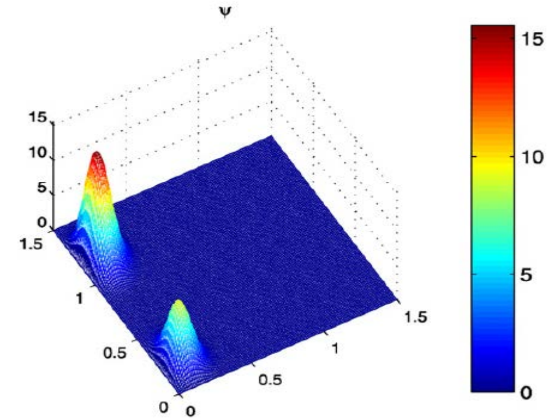
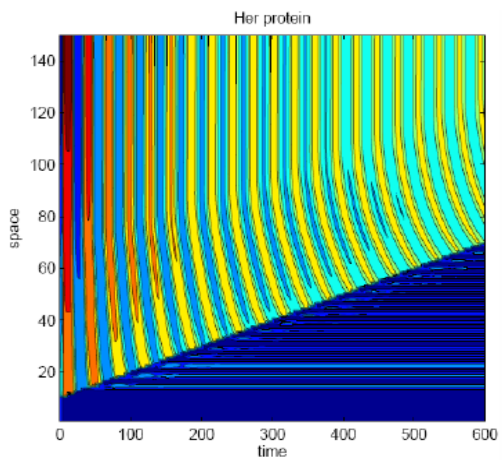
Prof. Chih-Wen Shih / Department of Applied Mathematics

Dynamical systems, Differential equations, Mathematical biology

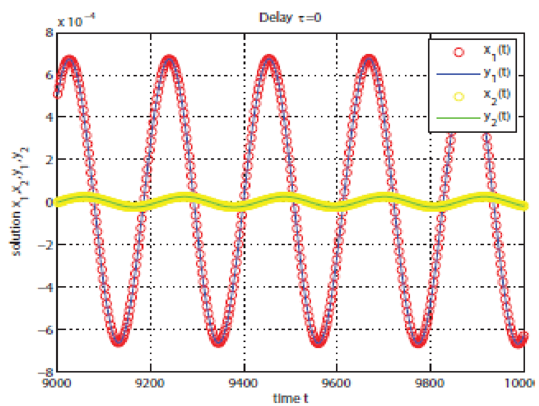
We are interested in developing mathematical methodologies to investigate nonlinear dynamical systems. The systems of particular interest are some mathematical models about biological processes or phenomena, including the ones on cell differentiation, somitogenesis, gene regulation, neuronal systems, and competitive species under dispersal. Mathematical analysis on the collective behaviors of these coupled cells or coupled systems enhances the understanding of these models. The other research interest is mathematical theory in neural networks.



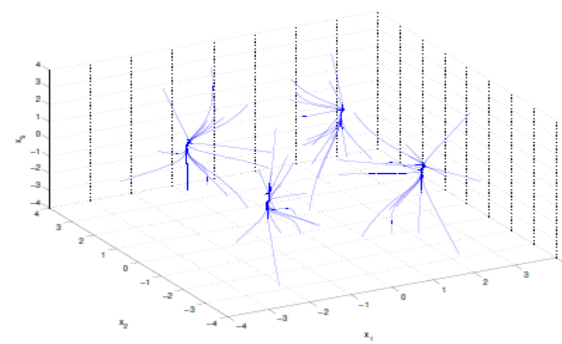
T-cell differentiation



Traveling wave patterns for somitogenesis of zebrafish



Synchronization for coupled FitzHugh-Nagumo systems



Multistability in neural networks

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Prof. Ming-Chia Li / Department of Applied Mathematics

Dynamical Systems, Chaos

In recent years, we study the followings:

- Coexistence of invariant sets with and without SRB measures in Henon family
- Topological dynamics for multidimensional perturbations of maps with covering relations and Liapunov condition
- Positive topological entropy for multidimensional perturbations of topologically crossing homoclinicity
- Covering relations for coupled map networks
- Stability of symbolic embeddings for difference equations and their multidimensional perturbations

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Prof. Yuan-Chung Sheu / Department of Applied Mathematics

Probability Theory, Stochastic Processes

We study the problem of disorder chaos in the spherical mean-_field model. It concerns the behavior of the overlap between two independently sampled spin configurations from two Gibbs measures with the same external parameters. The prediction states that if the disorders in the Hamiltonians are slightly decoupled, then the overlap will be concentrated near a constant value. Following Guerra‘s replica symmetry breaking scheme, we establish this at the levels of the free energy and the Gibbs measure.

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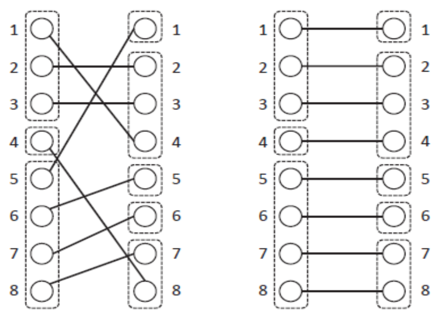
Prof. Chiu-Yuan Chen / Department of Applied Mathematics

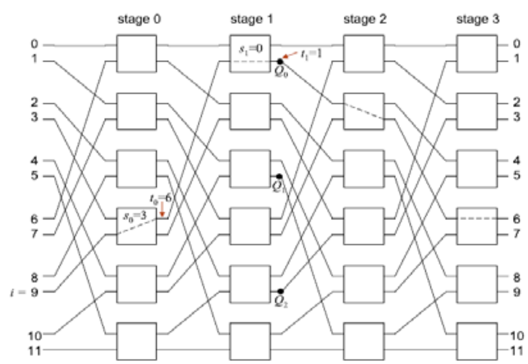
Graph Theory, Computer Algorithms, Interconnection Networks and Wireless Networks

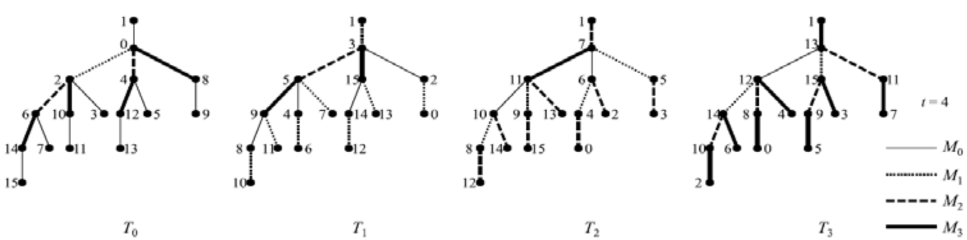
Recent Research Projects

- The application of graph theory to the localization and routing problems in wireless sensor networks
- Distance-two coloring for the adjacency graphs of wireless sensor networks
- The applications of graph theory to wireless sensor networks (data aggregation and localization)



(a) (b)





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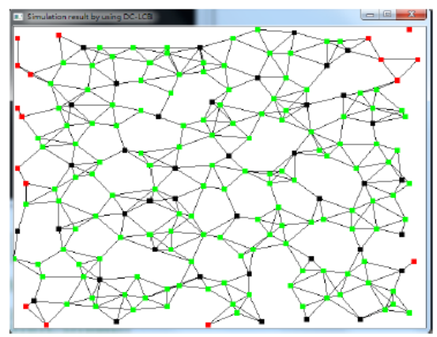
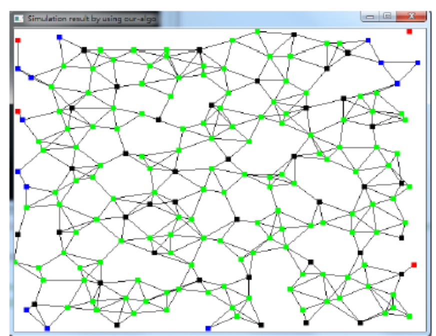
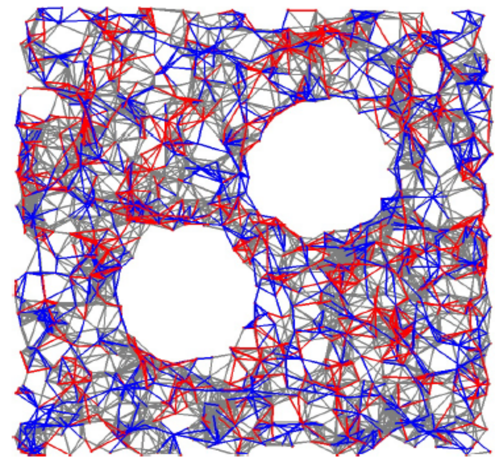


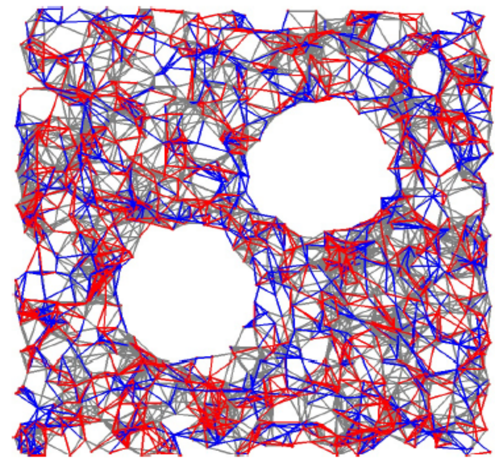
(a)



(b)



(a) The planarization constructed by ZJC-algorithm.



(b) The planarization constructed by our algorithm.

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Prof. Li-Ming Yeh / Department of Applied Mathematics

Operator Theory, Matrix Analysis, Numerical Ranges

We are interested in transport and diffusion problems in heterogeneous media. These problems arise from contaminant flows in the subsurface, heat transfer in two-phase media, stress in composite materials, etc. Our attention is mostly on the mathematical modeling, convergence analysis, and numerical computations.

Consider an elliptic equation in a periodic domain with period size ε. It is known that if ε tends to 0, the solution of the elliptic equation approaches a solution of a simple macroscopic equation. Moreover, a convergence estimate can be derived. Therefore, we would like to ask the same questions for realistic problems. If a mathematical model for a realistic problem is available, is it possible to find a simple macroscopic model so that the solution of the simple model still keeps properties close to those of the original realistic problem when measured on long space-time scales? If yes, can we derive a convergence estimate for the realistic solution? Also is it possible to find a simple way to compute the solution of the original realistic problem?

To answer these questions, some basic tools are necessary, for example, knowledge of partial differential equations and ergodic theory, understanding of functional spaces and homogenization methods, and numerical methods.

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Prof. Hung-Lin Fu / Department of Applied Mathematics

Combinatorial Design, Graph Theory and their Applications

My recent research includes the following topics:

1. Study *Group Testing with various models* which are applicable in computational molecular biology.

2. Construct *conflict-avoiding codes* by way of special sequences which we constructed and weighted matchings with suitable models.

3. Use the new idea we developed called *core cluster* to find the *optimal average information ratio* of perfect secret-sharing schemes for the access structures based on graphs.

4. Obtain good adaptive algorithms in *finding hidden graphs and hypergraphs*, this result is important in DNA sequencing.

5. Construct *codes with the identifiable parent property* for multimedia fingerprinting.

6. Find *the global packing number* of special networks which are useful in communication design.

7. Find the *vertex feedback number* of graphs which are of good application in preventing network deadlocks.

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Prof. Michael Fuchs / Department of Applied Mathematics

Analytic Combinatorics, Discrete Probability Theory, Analysis of Algorithms, Mathematical Biology, Metric Number Theory

My research work is concerned with several areas in Discrete Mathematics such as Combinatorics, Discrete Probability Theory and Number Theory. Most of the problems I worked on in recent years arose either from Theoretical Computer Science or Biology (for two figures concerning an area in Algorithms and Data Structures I worked on over the last couple of years see below). A practical problem must normally have at least two of the following three flavors in order that it sparks my interest: (i) combinatorial, (ii) probabilistic, or (iii) analytical. On the theoretical side, I am interested in counting problems in Combinatorics and Metric Diophantine approximation.

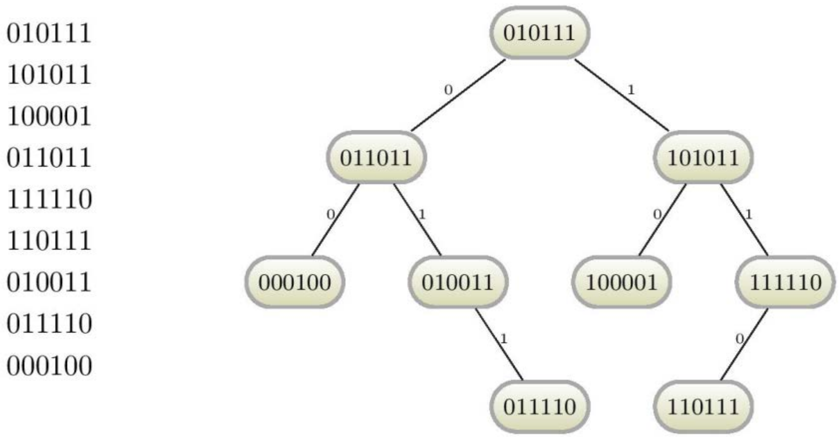

Figure 1: A digital search tree (DST) of 9 nodes

Let

$$G_2(\omega) = Q_\infty \sum_{j,h,\ell \geq 0} \frac{(-1)^j 2^{-\binom{j+1}{2}+j(\omega-2)}}{Q_j Q_h Q_\ell 2^{h+\ell}} \varphi(\omega; 2^{-j-h} + 2^{-j-\ell}),$$

where $Q_n := \prod_{j=1}^{n}(1-2^{-j})$, $Q_\infty := \lim_{n\to\infty} Q_n$ and

$$\varphi(\omega; x) = \begin{cases} \dfrac{\pi(1+x^{\omega-2}((\omega-2)x+1-\omega))}{(x-1)^2 \sin(\pi\omega)}, & \text{if } x \neq 1; \\ \dfrac{\pi(\omega-1)(\omega-2)}{2\sin(\pi\omega)}, & \text{if } x = 1. \end{cases}$$

Figure 2: Function from the analysis of the variance of the total path length of a DST (Fuchs, Hwang, Zacharovas; 2010)

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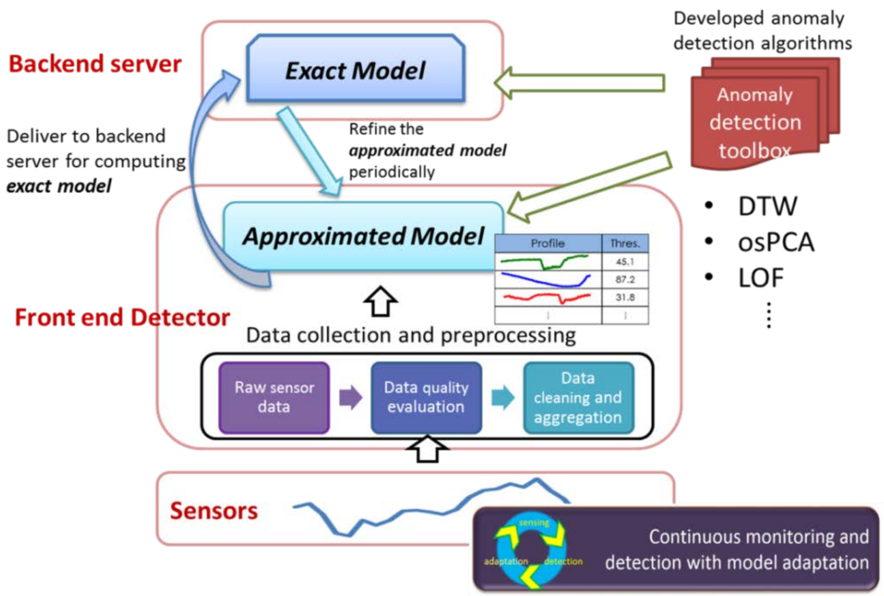
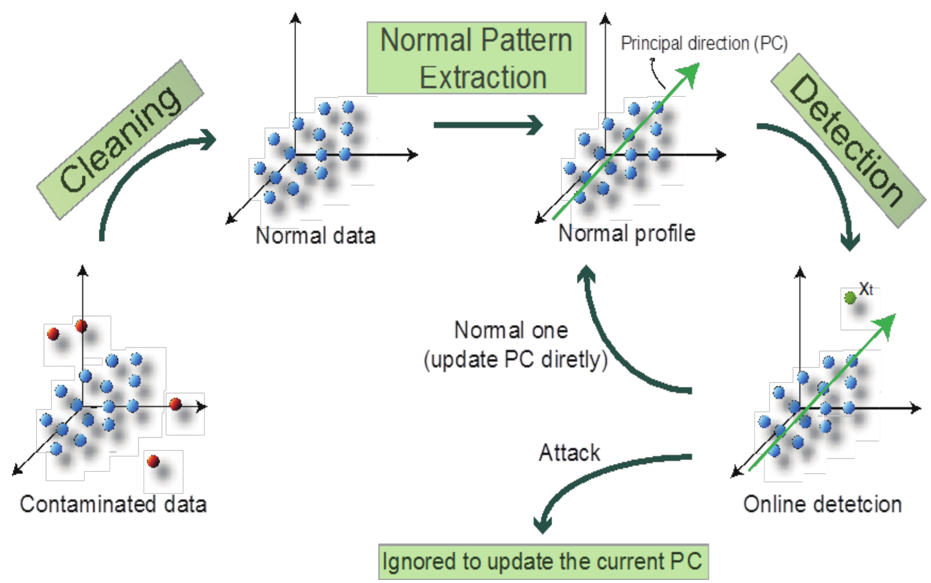
Prof. Yuh-Jye Lee / Department of Applied Mathematics

Data Science, Machine Learning, Numerical Optimization

My research is primarily rooted in optimization theory and spans a range of areas including machine learning, data mining, big data, numerical optimization and operations research. During the last decade, I have developed many learning algorithms in supervised learning, semi-supervised learning and unsupervised learning as well as linear/ nonlinear dimension reduction. My recent major research is applying machine learning to information security problems such as network intrusion detection, anomaly detection, malicious URLs detection and legitimate user identification. Currently, I focus on online learning algorithms for dealing with large scale datasets based on stochastic optimization. I am interested in exploring numerical techniques such as accelerated stochastic gradient, Hessian inverse approximation and the second order information. The compressed sensing, dictionary learning and sparse coding are other major research interests. I believe that all these research topics play extremely important roles in Big Data as well as Internet of Things (IoT) data analytics.





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Prof. Shiah-Sen Wang / Department of Applied Mathematics

Variational Methods., Geometric Measure Theory

- In the theory of calculus of variations, we are mainly interested study the partial regularities and singular structures of the minimizing mappings of energy functionals under various conditions originated from geometry and physics and their relations with the geometric and topological structures of the target spaces.

- Quantitative Geometric Measure Theory: For some subsets of Euclidean space, we look for suitable Hausdorff measures so that these subsets are appreciable with respect to these measures. Using these measures, we can decompose the subset into the union of subsets of different dimensions, study the geometric properties of each subset, for example, smoothness of the set and its curvatures and investigate how these subsets are patched back to the original subset.

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Prof. Jong-Eao Lee / Department of Applied Mathematics

Riemann Surface Theory, Theory of Classical Mathematical Functions, Periodic Solitons Theory of nonlinear evolution equations, and the Applications to the waves

We develop the periodic soliton theory of exactly integrable systems (all are universal nonlinear evolution equations) on Riemann surfaces of genus N, and apply it to generic waves.

Three important schemes are involved (each in both theoretical and numerical aspects) :

(a) develop the correct complex analysis and techniques of evaluation of path integrals on Riemann surfaces of genus N with various algebraic structures. This is the most fundamental and important tool in doing research waves.

(b) study the classical mathematics such as the theory of Elliptic functions, the Theta functions, and the Jacobian Elliptic functions. It is the theoretic foundation to the theory of Riemann surfaces and to the wave theory.

(c) Apply the theory and numerical techniques in (a, b) to analyze the exactly integrable systems such as Korteweg-de Vries, sine-Gordon and nonlinear Schrdinger universal partial differential equations which are universal mathematical models for generic waves.

The wave theory need much more different mathematical theory to analyze, and is still a wide-open field. Yet, the periodic soliton theory is already successfully applied to generic wave theory sush as water waves(deep, shallow, long, short), laser light, in acoustics, in plasmas, and network signals, etc.

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Prof. Yi-Jung Hsu / Department of Applied Mathematics

Differential Geometry

My primary research interests include the following major parts:

(a) Eigenvalue problem: Estimates of the first eigenvalue for compact or complete Riemannian manifolds, gap between closed eigenvalues, compare Dirichlet and Neumann eigenvalues.

(b) Global pinching problem: For constant mean curvature hypersurfaces, minimal hypersurfaces, and Willmore hypersurfaces in the unit sphere.

(c) Construct algebraic minimal hypersurfaces of degree 3 and 4 in the unit sphere.

(d) Existence Problem of harmonic morphisms.

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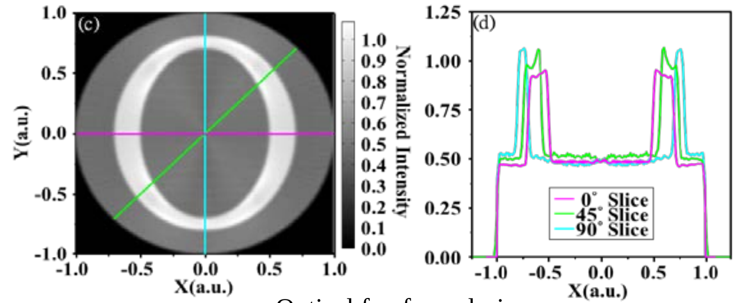
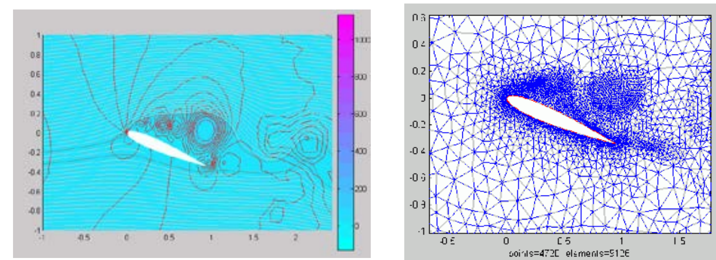
Prof. Chin-Tien Wu / Department of Applied Mathematics

Numerical PDE, Finite element, Multigrid, 3d image processing

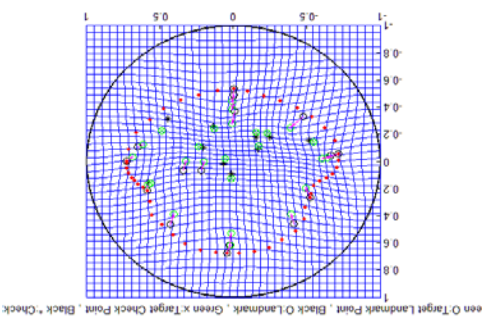
I am interesting in scientific computing and its applications. In particular, we use finite element method to solve problems from fluid dynamics, elastic mechanics, and geometric optics. In fluid dynamic, we simulate incompressible flow, shallow water and thin film. Robust multigrid methods combined with Krylov iteration are employed to speed up our simulator. In elastic mechanics, we solved the non-linear geometric deformation of thin shell with composite or piezoelectric material. We also apply large diffeomorphic metric map to compute the deformation of 3d images. In geometric optics, we constructed non-image freeforms by solving the Monge-Ampere equation using high order finite element and optimized the design using quantum particle swarm method. Recently, we like to further study on topics including 3d modeling, video tracking and machine learning etc.



Optical freeform design

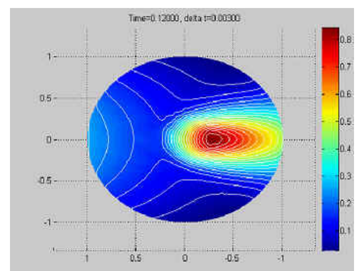


Flow simulation around airfoil

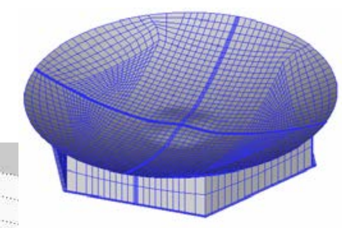


Landmarks registration
Using LDDMM

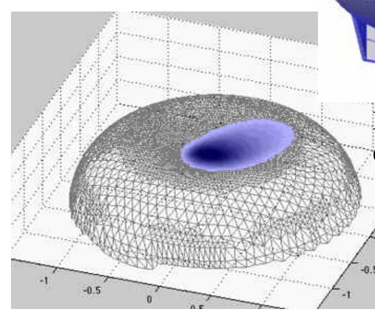
3D face morphing
Using LDDMM



External Heating
On rotating sphere



Deformation of a
composite reflector



Shallow water on a
blood cell surface

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Prof. Guan-Yu Chen / Department of Applied Mathematics

Stochastic process, Markov chain mixing, Cutoff phenomenon

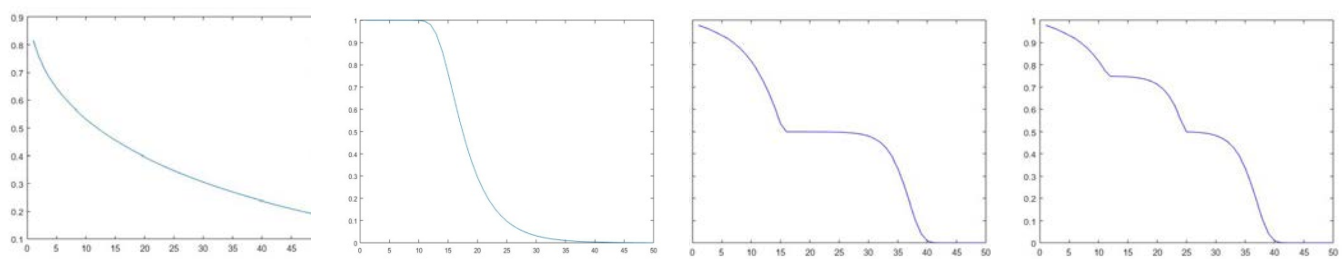
The Markov chain Monte Carlo (briefly, MCMC) method is a well-designed algorithm in sampling probability measures on discrete sets. Along with the Metropolis-Hasting algorithm, one may implement the MCMC method only with the local information of the targeted distributions, say the relative ratio, but without the information of the normalizing constant. When the MCMC method is simulated, it is important to select a (deterministic or random) time, say T, to stop the algorithm for sampling. Theoretically, the stopping time T can be the mixing time or the coupling time but none of them is easy to achieve.

The cutoff phenomenon is a phase-transit phenomenon in the evolution of Markov chains. This concept was introduced by Aldous and Diaconis in early 1980s in order to catch up the observation that the distribution of Markov chain is far from its stationarity before a time S and, after a relatively short period compared with S, the distribution turns out to be almost the limiting distribution. When a cutoff exists in a MCMC algorithm, the time S can be a good candidate for the stopping time of algorithm.

The MCMC method arises in many disciplines including the statistic physics, computer science, molecular biology, mathematical finance and more. From the viewpoint of interdisciplinary research, the underlying machinery can be very complicated, e.g. random walks on disordered random media and Markov processes on compact Riemannian manifolds, and a quick formula on the stopping time T and the cutoff time S will be very challenging but highly expected.

The following are some future perspectives we are interested in.
1) Spectral analysis of graph connection Laplacian
2) Random walks on random media
3) Inhomogeneous Markov chains

Figures: Those figures display some distance functions. From left to right, they are respectively Markov chains (1)without cutoff; (2)with cutoff; (3)with one bottleneck; (4)with two bottlenecks.



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Prof. Shu-Ming Chang / Department of Applied Mathematics

Scientific Computations, Dynamical Systems

In Scientific Computations, we focus on **Numerical Computations of Nonlinear Schrodinger's Equations** that there are two researching topics in this field: (1) The Ground State and Excited States for the Bose-Einstein Condensates (BECs) (see Fig. 1), (2) Stability Analysis in the Soliton Waves (see Fig. 2). Then in Dynamical Systems, we focus on **Chaotic System and its Applications** that there are also two researching topics in this field: (3) Investigation on Chaotic Behavior, (4) Digital Chaotic Generators in Secure Communication (see Fig. 4).

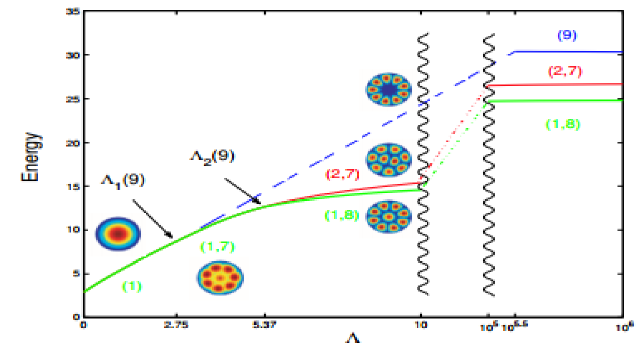

Fig. 1. The ground state and excited states of the Nine BECs.

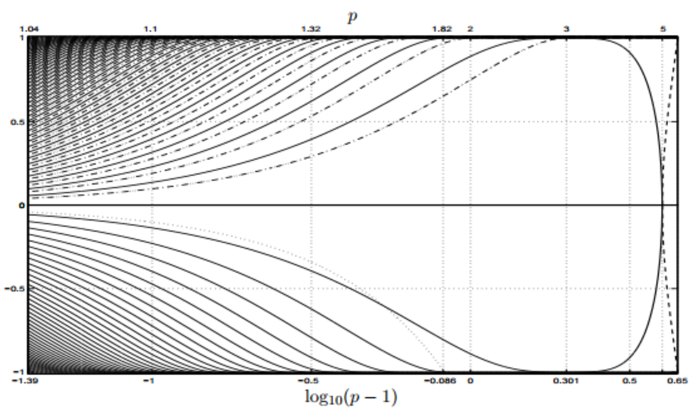

Fig. 2. The soliton wave changes to unstable from stable at the parameter p = 5.

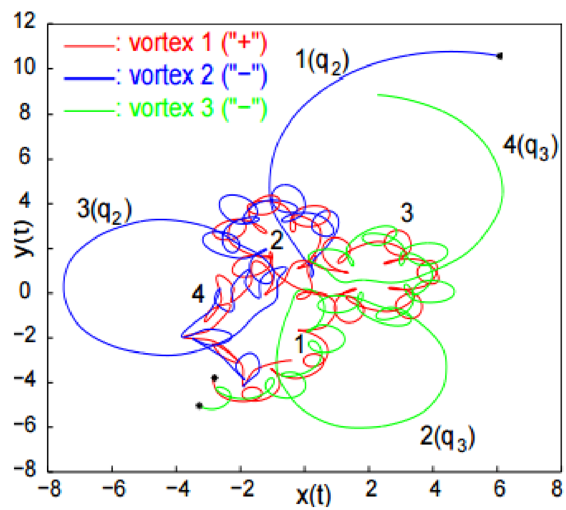

Fig. 3. Chaotic behavior for the system with three charge particles.

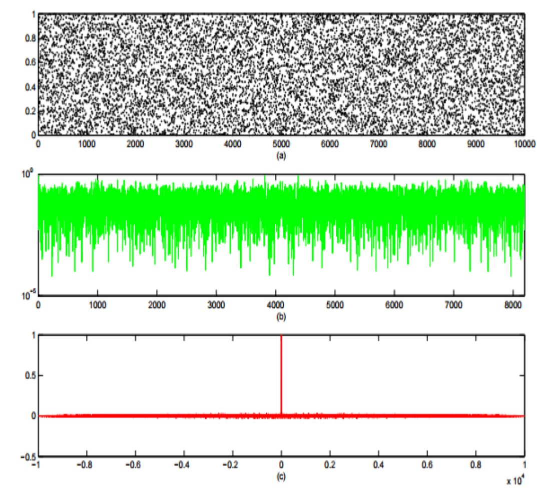

Fig. 4. (a) Digital chaotic signal.
(b) Spectral analysis in the signal.
(c) Co-relation Analysis in the signal.

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Prof. Kuo-Zhong Wang / Department of Applied Mathematics

Operator Theory, Matrix Analysis, Numerical Ranges

The main work of our research on the numerical range is to analysis theoretically the correlation between numerical ranges, functional analysis and matrix analysis.

The numerical range and numerical radius are very useful for studying linear operators acting on Hilbert spaces or Banach spaces. For instance, it is known that the close set of the numerical range always contains its spectrum, and many geometrical properties of the numerical range correlate with its spectrum. The spectrum and the numerical range are useful tools for studying operators and matrices. In this respect we're now approaching the research about product numerical ranges and it is used in the study of quantum information science. On the other hand, we have also been interest in studying the numerical range of a special matrix such as a partial isometry matrix or a stochastic matrix.

A generalization of the numerical range has been applied widely in many fields. The classical numerical range is also generalized to valuable different types which play important rolls in many fields. For instance, the higher-rank numerical range is applied in quantum physics, the C-numerical radii is applied in unitary similarity invariant norms, the joint numerical range is applied in the joint spectrum and joint spectral norm. I’m interested in these questions, and I’m looking forward to cooperating with experts in this field.

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Prof. Ming-Hsuan Kang / Department of Applied Mathematics

Operator Theory, Matrix Analysis, Numerical Ranges

My research interests include algebraic groups , representation theory and its application. My collaborates and I have a series works about zeta functions of complexes, which are classifying spaces of uniform lattices in the algebraic groups. We are also interested in the spectral behavior of these zeta functions, like the distributions of zero and poles.

Besides, we are also interested in the philosophy of the field with one element, which reduces the problems on p-adic algebraic groups to the problems on affine Weyl groups. We also have some works on Generalized Poincare series on affine Weyl groups and Iwahori-Hecke algebras.

On the other hands, we are also very interested in the applications of pure mathematics in other disciplines. For instance, we apply the theory of extremal lattices and representation theory to spherical Monte Carlo methods. Moreover, we also use representation theory to study the spectral properties of toroidal fullerenes.

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Prof. Ming-Cheng Shiue / Department of Applied Mathematics

Numerical Analysis, Scientific Computing, Geophysical Fluid Dynamics

Currently, my research interests focus on analysis and computation of the Partial Differential Equations (PDEs) arising from geophysical fluid dynamics. For example, equations related to weather prediction and oceanography are the inviscid Primitive Equations (PEs) and the Shallow Water Equations (SWEs).

In Figure 1, the basic level of physical complexity in geophysical fluid dynamics is presented. The Navier-Stokes equations govern the motion of the fluid. In the ocean or atmosphere, due to the thin layer structure (the ratio of the vertical scale of the domain to the horizontal scale is relatively small), Navier-Stokes equation can be simplified in the form of Primitive equations. Shallow water equations are derived from the first mode of the Primitive equations.

In addition, I am also interested in stochastic differential equations(SDEs)/stochastic partial differential equations(SPDEs) which give us different points of view to understand what the world is. This approach also has been suspected that fluid equations with noise perturbation such as the stochastic Navier-Stokes Equations(SNSEs) and stochastic Euler Equations might be an important mathematical model for the turbulence of a fluid with a high Reynold number.

The following issues are focused:

1. Non-reflecting boundary conditions
2. Time periodic flows
3. Long-time stability analysis

For more details, please see my homepage (Figure 2).

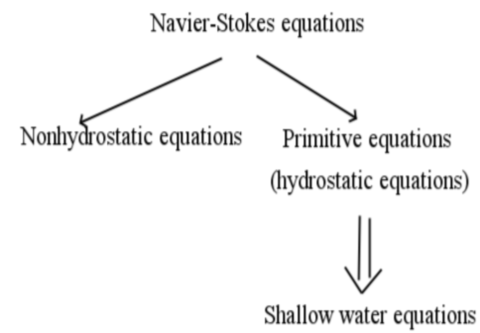

Figure 1:
Level of physical complexity

Figure 2:
QR code for My homepage

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Prof. Chi-Hin Chan / Department of Applied Mathematics

Analytical, Geometrical, and Topological Properties of Viscous Incompressible Fluid Flows, Partial Differential Equations

The motion of an incompressible Newtonian fluid is described by the incompressible Navier- Stokes equation in the Euclidean space setting. Though the standard derivation of the incompress- ible Navier-Stokes equation based on the Newton's second law was well-understood already in the 19 century, serious mathematical study of viscous incompressible fluid flows from the view point of Partial Differential Equations only began with the existence theory of Leray-Hopf weak solutions to the incompressible Navier-Stokes equation as established by Leray (1930's) and Hopf (1950's). Since then, P.D.E. specialists in this area had devoted great efforts in obtaining the classical smoothness property of Leray-Hopf weak solutions under suitable space-time integrability condi- tions imposed on the weak solutions themselves. However, it is still a long standing open problem to decide whether the breakdown of classical smoothness of Leray-Hopf weak solutions could occur.

My research focuses on the study of analytical, geometrical, and topological properties of viscous fluid flows taking place in a curved space setting. In the past few years, I and professor Magdalena Czubak made a simple yet striking observation about the non-uniqueness phenomena of finite energy viscous fluid flows on a negatively curved surface of constant sectional curvature. and subsequentally established the proper framework of weak solutions which restores uniqueness in the same setting. In the near future, we will try to find a deeper connection between mathematical properties of fluid flows taking place in a curved space setting and those of fluid flows taking place in the standard flat space setting.

$$\begin{aligned} \partial_t u - \triangle u + u \cdot \nabla u + \nabla P = 0, \\ \operatorname{div} u = 0. \end{aligned} \qquad (0.1)$$

$$\partial_t \omega - \triangle \omega + [u, \omega] = 0. \qquad (0.2)$$

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Prof. Hsin-Yuan Huang / Department of Applied Mathematics

Mathematical Physics, and Nonlinear Partial Differential Equations

My research work centers around two broad topics: the analysis of nonlinear elliptic Partial Differential Equations arising from gauge theoryand the variational method on the Newtonian N-body problem.

(A) In the last decade, various **Chern-Simons theories** have been studied in various physical model, such as relativistic Chern-Simon theory of high temperature superconductivity, Lozano-Marques-Moreno-Schaposnik model of bosonic sector of N=2 supersymmetric Chern-Simons-Higgs theory, and Gudnason model of N=2 supersymmetric Yang-Mills-Chern-Simons-Higgs theory. Those Chern-Simons models, after suitable ansate, can be reduced to nonlinear elliptic PDEs. I am interested in the following research topics.

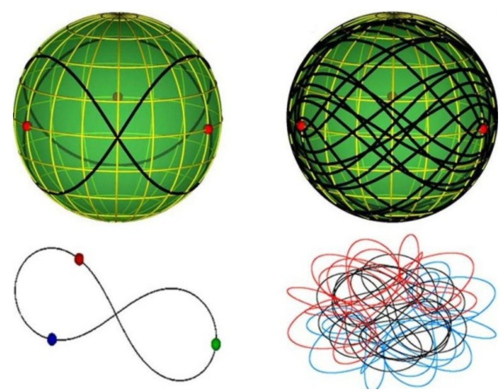
[1] limiting phenomenon of solutions.
[2] Shape estimates on the bubbling solutions.
[3] Sufficient and necessary conditions for the existence of bubbling solutions.

Chern-Simons-Higgs Equation $$\Delta u + \frac{1}{\varepsilon^2} e^u (1 - e^u) = 4\pi \sum_{j=1}^{N} \delta_{p_j}$$

(B) In the Newtonian **N-body problem**, the motion of N particles is determined by a system of second order differential equations. The least action principle suggests that the orbits extremize the Lagrangian action functional. However, the variational method had not been successfully applied to the Newtonian N-body problem until Chenciner and Montgomery's remarkable work in 2000. The main difficulty is to avoid unnecessary collisions occurred in the minimizers of the Lagrangian action functional. Collisions make the potential functional become infinite and the action may still be finite. I am interested in the following research topics.

[1] Existence of periodic solutions by variational method.
[2] Behaviors on the collision orbits and parabolic orbits by variational method.

Newtonian N-body Problem $$m_i \frac{d^2 q_i}{dt^2} = - \sum_{j=1, j\neq i}^{N} \frac{m_i m_j (q_i - q_j)}{||q_i - q_j||^3}, \quad i = 1 \cdots N$$



“Figure eight orbit" and “yarn orbit“ to the three-body problem can be viewed on an abstract shape-sphere (*top*) or in real space (*bottom*).
Milovan Šuvakov and Veljko Dmitrašinović, *Phys. Rev. Lett.*, (2013); Milovan Šuvakov and Veljko Dmitrašinović /University of Belgrade

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Prof. Te-Sheng Lin / Department of Applied Mathematics

Mathematical modeling, Scientific computing, Fluid mechanics, Asymptotic analysis

- The focus of my research is concerned with the development of analytical and computational tools for the problems that arises in fluid dynamics, currently in thin liquid films, and further to communicate with scientists from other disciplines to solve engineering problems in practice.

- My current research topics includes (1) Fingering instabilities in Newtonian films; (2) Modeling and analysis of nematic droplets and films; (3) Coherent structures in non-local dispersive active-dissipative systems; (4) Pulse interaction and bound state formation in electrified falling films. For example, Figures. 1 and 2 present 2D and 3D numerical simulations of fingering instabilities arising in falling liquid films, respectively. Figure 3 presents the pattern formation on a thin film of nematic liquid crystal. Figure 4 shows the simulation that represents a liquid film sheared by a turbulent gas.

Figure 4

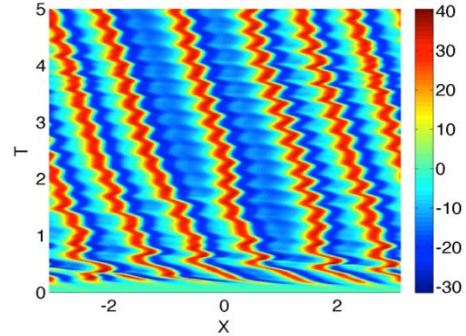


Figure 1

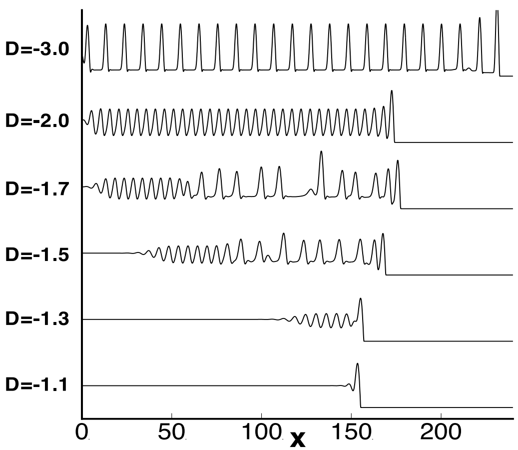


Figure 2

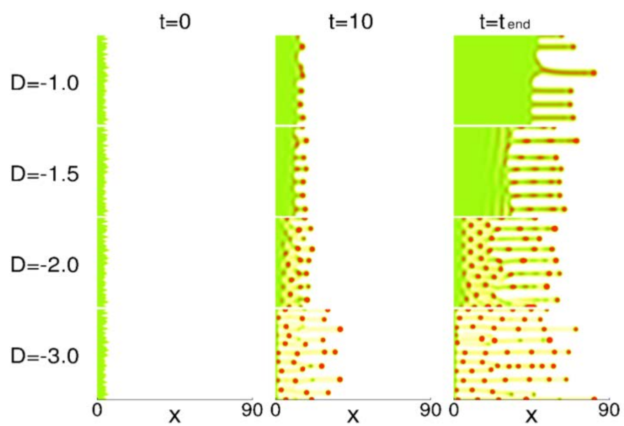
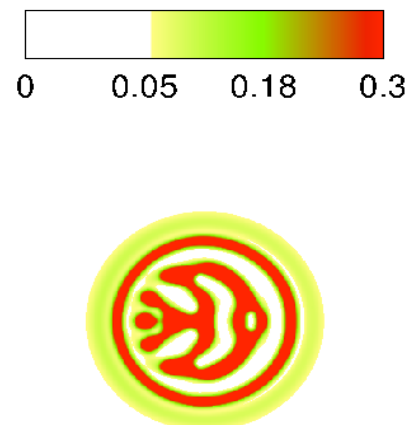


Figure 3



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Prof. Daniel Spector / Department of Applied Mathematics

Harmonic Analysis, Partial Differential Equations, Calculus of Variations, Geometric Measure Theory

A general principle in many areas of mathematics and science is that the dynamics of a system tend to evolve in a direction which reduces the available energy. This is the least action principle, which postulates the possibility of defining an energy - a functional whose input is taken from a set of possible states - and supposing that the output or "action" of that state prefers local minima. From this perspective, the calculus of variations is very important, since it is precisely the study of the extrema of functionals.

$$S = \int_{t_0}^{t_1} L(t, \mathbf{x}(t), \dot{\mathbf{x}}(t))\, \mathrm{d}t$$

Our research focuses on the regularity of minimizers and how the qualitative properties depend on the differential order of the energy. Here we utilize an object whose study in the literature is surprisingly quite sparse – Riesz fractional gradients – and early research suggests that although there are significant differences in the properties of energies of integer differential order, there is no difference in the regularity or qualitative properties.

$$\frac{\partial L(t, \mathbf{x}, \mathbf{v})}{\partial v_i} = m v_i = p_i$$

Thus far we have obtained several new existence and convergence results for the Partial Differential Equations we consider, as well as new inequalities that provide a nice complement to more classical results. Future research will look to new regularity results for non-linear problems as well as the application to physical problems modeled by these energies.

$$\frac{\partial L(t, \mathbf{x}, \mathbf{v})}{\partial x_i} = -\frac{\partial U(\mathbf{x})}{\partial x_i} = F_i(\mathbf{x})$$

$$L(t, \mathbf{x}, \mathbf{v}) = \frac{1}{2} m \sum_{i=1}^{3} v_i^2 - U(\mathbf{x})$$