华南数学应用与交叉研究中心
South China Research Center for Applied Mathematics and Interdisciplinary Studies

CAMIS-SCNU
Workshop

界面问题数值方法及应用研究论坛

Workshop on Computational Methods for Interface Problems & Applications

Brochure
会议手册

South China Research Center for Applied Mathematics
and Interdisciplinary Studies (CAMIS), South China Normal University
华南师范大学华南数学应用与交叉研究中心

Guangzhou, China
May 24-26, 2019

Address: Zhong Shan Avenue West 55, Tianhe District, Guangzhou 510631, China
地址：广东省广州市天河区中山大道西55号　　邮编：510631
Website: http://camis.scnu.edu.cn/

1. Useful Information

(1) Timetable

Workshop on Computational Methods for Interface Problems & Applications May 24-26, 2019			
Time	**May 24th(Friday)**	**May 25th (Saturday)**	**May 26th (Sunday)**
8:50-9:00	Opening remarks		
9:00-9:30	**Xiaoping Xie**	**Shuwang Li**	**Jizu Huang**
9:30-10:00	**Xinpeng Xu**	**Xiufang Feng**	**Jingrun Chen**
10:00-10:30	Coffee break	Coffee break & Photos	Coffee break
10:30-11:00	**Wenjun Ying**	**Jiang Yang**	**Rongliang Chen**
11:00-11:30	**Dong Wang**	**Chenliang Li**	**Xiaoding Shi**
11:30-12:00	**Yanxiang Zhao**	**Yan Wang**	**Dan Hu**
12:00-14:00	Lunch	Lunch	12:00-12:10 Closing Remarks 12:10 Lunch
14:00-14:30	**Qinghai Zhang**	**Wenqi Yao**	**Departure**
14:30-15:00	**Zhiyue Zhang**	**Jinru Chen**	
15:00-15:30	**Huangxin Chen**	**Xinlong Feng**	
15:30-16:00	Coffee break	Coffee break	
16:00-16:30	**Li Luo**	**Lei Zhang**	
16:30-17:00	**Qiaolin He**	**Xiaoyang Xu**	
17:00-17:30	**Jianfang Lu**		
17:30—20:00	Dinner	Banquet	

(2) Address

①**Accommodation:** Huashi Hotel (华师大厦酒店)

②**Hotel Address:** Zhongshan Avenue West No. 69, Tianhe District, Guangzhou 510631, China

(广州市中山大道西 69 号华师大厦酒店（原华师粤海酒店））

③**Talk venue:** South China Research Center for Applied Mathematics and Interdisciplinary Studies (CAMIS),

South China Normal University （华南师范大学华南数学应用与交叉研究中心）

(3) Map: Huashi Hotel-- CAMIS

(4) Map: CAMIS-- Taoyuan

2.Programme (日程)

Date	Time	Activity	Venue
May 23th, Thurs.	16:00-17:00	Registration (注册)	**The hall of CAMIS** 交叉中心一楼大厅
	17:00-19:00	Welcome dinner	Taoyuan Canteen 陶园二楼自选区
May 24th, Fri.	08:30-08:50	Registration (注册)	**Room 111 of CAMIS**
	08:50-09:00	Opening remarks by **Prof. Zhouping XIN and Prof.Weizhu BAO**	
	Session 1. Chairman: **Prof.Weizhu BAO**		
	09:00-9:30	*Extended HDG methods for second order elliptic interface problems* **Prof. Xiaoping XIE (谢小平)**	
	9:30-10:00	*Dynamics of evaporating thin film: phase field modeling and simulations* **Prof. Xinpeng Xu(徐新鹏)**	
	10:00-10:30	Coffee break	
	Session 2. Chairman: **Prof.Zhilin LI**		
	10:30-11:00	*Analysis on the potential theory based Cartesian grid method for interface problems* **Prof. Wenjun YING(应文俊)**	
	11:00-11:30	*A data-driven approach for interface motions* **Prof. Dong WANG（王东）**	
	11:30-12:00	*Phase Field Model of Cell Migration* **Prof. Yanxiang ZHAO（赵雁翔）**	
	12:00-14:00	Lunch（午饭）	Taoyuan Canteen 陶园二楼自选区
	Session 3. Chairman:**Prof. Xiaoping XIE**		
	14:00-14:30	*MARS: An Analytic and Computational Framework for Incompressible Flows with Moving Boundaries* **Prof. Qinghai ZHANG(张庆海)**	
	14:30-15:00	*A hybrid asymptotic and augmented compact FVM for nonlinear singular differential equation and its application in the interface problem* **Prof. Zhiyue ZHANG (张志跃)**	

	15:00-15:30	HDG methods for the Maxwell equations **Dr. Huangxin CHEN (陈黄鑫)**	
	15:30-16:00	Coffee break	
	Session 4. Chairman: **Prof. Yang XIANG**		
	16:00-16:30	*A parallel implicit discontinuous Galerkin method for two-phase flow problems on 3D unstructured meshes* **Dr. Li LUO (罗力)**	
	16:30-17:00	*The Lattice Boltzmann method for sloving fluid-structure interaction problem with Navier-slip boundary condition* **Dr. Qiaolin HE (贺巧琳)**	
	17:00-17:30	*A discontinuous Galerkin method with penalty for one-dimensional nonlocal diffusion problems* **Dr. Jianfang LU (卢键方)**	
	17:30	Dinner (晚饭)	Taoyuan restaurant 陶园二楼 围餐
May 25th, Sat.	Session 1. Chairman: **Prof. Xinpeng XU**		
	09:00-9:30	*Computation of an expanding or shrinking interface in a Hele-Shaw cell* **Prof. Shuwang LI**	
	09:30-10:00	*High Order Compact Finite Difference Scheme for Two Dimensional Helmholtz Equation with Discontinuous Coefficient* **Prof. Xiufang FENG(冯秀芳)**	
	10:00-10:30	Coffee break (Photos，集体照)	
	Session 2. Chairman: **Prof. Shuwang LI**		
	10:30-11:00	*An Analysis of Time-Fractional Allen-Cahn Equations* **Prof. Jiang YANG (杨将)**	
	11:00-11:30	*Time-extrapolation algorithm for diffusion and reaction equations* **Prof. Chenliang LI (李郴良)**	
	11:30-12:00	*Numerical methods for solid-state dewetting problems* **Prof. Yan Wang (王燕)**	
	12:00-14:00	Lunch (午饭)	Taoyuan Canteen 陶园二楼 自选区
	Session 3. Chairman: **Dr.Fanhai Zeng**		
	14:00-14:30	*Numerical methods for the study of transition events in fluctuating hydrodynamics* **Prof. Wenqi Yao(姚文琪)**	

	14:30-15:00	*Nonconforming Nitsche's Extended Finite Element Methods for Interface Problems* **Prof. Jinru CHEN(陈金如)**	
	15:00-15:30	*Superconvergence in H1-norm for a difference finite element method for 3D heat equation* **Prof.Xinlong FENG (冯新龙)**	
	15:30-16:00	Coffee break	
	Session 4. Chairman: **Prof. Jiang YANG**		
	16:00-16:30	*Modeling and simulation of an active swimmer in nematic liquid crystal* **Prof. Lei ZHANG(张镭)**	
	16:30-17:00	*An improved SPH method for simulating 3D dam-break flows with breaking waves* **Prof. Xiaoyang XU(许晓阳)**	
	17:30	Banquet (晚宴)	Taoyuan restaurant 陶园二楼围餐
April. 26th, Sun	Session 1. Chairman: **Prof. Tiezheng QIAN**		
	09:00-9:30	*A lattice Boltzmann model for 3D multiphase flows with moving contact line* **Prof. Jizu HUANG(黄记祖)**	
	09:30-10:00	*Multiscale modeling of current-driven magnetization dynamics* **Prof. Jingrun ChEN(陈景润)**	
	10:00-10:30	Coffee break	
	Session 2. Chairman:**Prof. Xiaoping WANG**		
	10:30-11:00	*Parallel Domain Decomposition Methods for Patient-specific Blood Flow Simulations* **Prof. Rongliang CHEN(陈荣亮)**	
	11:00-11:30	*Model of Compressible Iimmiscible Fluid with General Navier Boundary Condition* **Prof. Xiaoding SHI(施小丁)**	
	11:30-12:00	*An Adaptation Model for Slime Mold Physarum Polycephalum* **Dr. Dan HU (胡丹)**	
	12:00-12:10	Closing Remarks	
	12:10	Lunch	Taoyuan Canteen 陶园二楼自选区

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3.Abstract & Title

HDG methods for the Maxwell equations

Huangxin Chen(陈黄鑫) (Xiamen University)

In this talk we will introduce a new HDG method for the steady state Maxwell equations based on a mixed curl-curl formulation. We use a non-trivial subspace of polynomials of degree k+1 to approximate the numerical tangential trace of the electric field on the faces. If the dual operator of the Maxwell equation has adequate regularity, the order of convergence of L2-error for the electric field is k+2. From the point of view of degrees of freedom of the globally coupled unknown: numerical trace, this HDG method achieves superconvergence for the electric field without postprocessing. When we consider the Maxwell equations with low regularity of electric field, another HDG method and its a priori and a posteriori error estimates will be discussed. Some numerical results will be shown to demonstrate the efficiency of the HDG methods for the Maxwell equations.

Multiscale modeling of current-driven magnetization dynamics

Jingrun Chen(陈景润) (Soochow University)

Understanding magnetization dynamics in magnetic materials under external current control plays a vital role in magnetic storage devices, such as magnetoresistance random access memories and race-track memories. In this presentation, we will discuss how to model such a phenomenon at different spatial and temporal scales. Consequently, a series of models is obtained with increasing accuracy. Efficient numerical methods are also proposed and applied to a couple of prototypical devices, which produces consistent results with experiments. Of physical and technological interests, 1D surrogate model is also derived using the method of matched asymptotics, which explains the Walker's breakdown. The gap between the 1D model and the original model will also be discussed.

Nonconforming Nitsche′s Extended Finite Element Methods for Interface Problems

Jinru Chen(陈金如) (Nanjing Normal University)

We study P_1 nonconforming Nitsche’s extended finite element methods with interface unfitted meshes for elliptic/Stokes interface problems. By adding some penalty terms defined on the transmission edges to the discrete form, the stability of the discrete problems and optimal error estimates are derived in spite of the low regularity of the elliptic/Stokes interface problems. For the elliptic interface problems, it is shown that all results are independent of not only the diffusion parameters but also the position of the interface with respect to the mesh without other assumption for the interface. For the Stokes interface problems, all results are independent of the viscosity parameters. Numerical experiments validate theoretical results.

Parallel Domain Decomposition Methods for Patient-specific Blood Flow Simulations

Rongliang Chen(陈荣亮) (Shenzhen Institutes of Advanced Technology，Chinese Academy of Sciences)

Numerical simulation of blood flows in compliant arteries based on patient-specific geometry and parameters can be clinically helpful for physicians or researchers to study vascular diseases, to enhance diagnoses, as well as to plan surgery procedures. In this talk, we will discuss some scalable parallel domain decomposition methods for the simulation of blood flow in compliant arteries on large scale supercomputers. The blood flow is modeled by 3D unsteady incompressible Navier-Stokes equations with a lumped parameter boundary condition, which are discretized with a stabilized finite element based on unstructured meshes in space and a fully implicit method in time. The large scale discretized nonlinear systems are solved by a parallel Newton-Krylov-Schwarz method. Several mathematical, biomechanical, and supercomputing issues will be discussed in detail, and some numerical experiments for patient-specific arteries will be presented. We will also report the parallel performance of the methods on a supercomputer with a large number of processors.

Superconvergence in H1-norm for a difference finite element method for 3D heat equation

Xinlong Feng(冯新龙) (Xinjiang University)

In this paper, we propose a novel difference finite element (DFE) method based on the P_1-element for the 3D heat equation on a bounded domain $\O=\o\times (0,L_3)$. One of novel ideas of this paper is to use the second-order backward difference formula (BDF) combining DFE method to overcome the computational complexity of conventional finite element (FE) method for the high-dimensional parabolic problem. Error estimate of the semi-discrete difference solution and fully discrete finite element solution are derived respectively. Finally, numerical tests are presented to show the second-order H^1-convergence results of the proposed DFE method for the 3D heat equation.

High Order Compact Finite Difference Scheme for Two Dimensional Helmholtz Equation with Discontinuous Coefficient

Xiufang Feng(冯秀芳) (Ninxia University)

In this paper, we combined the finite volume method and finite difference method to solve two dimensional Helmholtz equation with discontinuous coefficient. Through numerical discrete, high order compact difference scheme is developed for regular point and interface, numerical examples are showed the efficiency and accuracy of the scheme presented.

The Lattice Boltzmann method for sloving fluid-structure interaction problem with Navier-slip boundary condition

Qiaolin He(贺巧琳) (Sichuan University)

In the conventional immersed boundary-lattice Boltzmann method (IB-LBM), the lattice

Boltzmann equation (LBE) is solved by adding the external force IBF. And the immersed boundary body force (IBF) is explicitly computed in advance, such as penalty method, direct forcing method and momentum exchange method. But conventional IB-LBM cannot enforce the no-slip boundary condition at the immersed interface. The no-slip boundary condition as well as Navier-slip boundary condition can be satisfied by using the velocity correction scheme and solving the motion equation of fluid-particle mixture. The solution procedure of LBE is different from the conventional IB-LBM, the Runge-Kutta lattice Boltzmann method is used to improve both stability and preferences. In the meanwhile, the stress σ can be calculated explicitly by the Chapman-Enskog Analysis for LBE.

An Adaptation Model for Slime Mold Physarum Polycephalum

Dan Hu(胡丹) (Shanghai Jiao Tong University)

A Physarum Polycephalum is a single-celled animal that appears to be able to form intelligent network structures. Such a network is used for transportation of mass and energy in its body. There have been a few models discussing the formation dynamics of the networks structure. Nevertheless, very few has been discussed about the biological stimuli that drive such adaptation models. In this talk, we present a mathematical model to show that by an adaptation dynamics in response to local shear stress on the cell wall, the Physarum Polycephalum is able to minimize the total energy cost in fluid delivery. Furthermore, using an asymptotic analysis, we reduce the three-dimensional fluid flow to a two-dimensional flow and obtain an adaptation model of the thickness of Physarum Polycephalum. This model appears to be very similar to our previous model on the initiation of biological transport networks, thus can lead to the formation of networks structure with optimized energy cost.

A lattice Boltzmann model for 3D multiphase flows with moving contact line

Jizu Huang(黄记祖) (Chinese Academy of Science)

In this talk, we discuss an efficient lattice Boltzmann model for the two-phase moving contact line problem. The Navier-Stokes and Cahn-Hilliard equations are recovered from the lattice Boltzmann model. In order to describe the behavior of the contact line motion on the boundary, we incorporate the generalized Navier boundary condition by the non-equilibrium extrapolation method. The proposed method is easy to implement and retains the advantage of the standard lattice Boltzmann method. Several three dimensional numerical tests are carried out to verify the proposed method.

Time-extrapolation algorithm for diffusion and reaction equations

Chenliang Li(李郴良) (Guilin Electronic Technology University)

In this topic, we present a time-extrapolation method for solving the diffusion and reaction equations. This method can provide good initial values by linear combination of previous several level solutions to accelerate the rate of convergence.

Computation of an expanding or shrinking interface in a Hele-Shaw cell

Shuwang Li (Illinois Institute of Technology)

The Hele-Shaw problem is a classical example for studying interface dynamics or systems driven out of equilibrium. In this talk, I will first discuss numerical issues related to long-time computation of moving interfaces. Then I will present a time adaptive scheme for efficiently computing the dynamics of a moving interface. The idea is to design a time-space mapping such that in the new time scale, the interfaces can evolve at arbitrarily fast or slow speed. We then show numerical examples and present largest (expanding interface) and smallest (shrinking interface) Hele-Shaw simulation up to date.

A discontinuous Galerkin method with penalty for one-dimensional nonlocal diffusion problems

Jianfang Lu (卢键方) (South China Normal University)

In this talk, we propose and analyze a new discontinuous Galerkin method for solving one-dimensional steady-state and time-dependent ND problems, based on a formulation that directly penalizes the jumps across the element interfaces in the nonlocal sense. We show that the proposed discontinuous Galerkin scheme is stable and convergent. Moreover, the local limit of such DG scheme recovers classical DG scheme for the corresponding local diffusion problem, which is a distinct feature of the new formulation and assures the asymptotic compatibility of the discretization. Numerical tests are also presented to demonstrate the effectiveness and the robustness of the proposed method.

A parallel implicit discontinuous Galerkin method for two-phase flow problems on 3D unstructured meshes

Li Luo(罗力) (King Abdullah University of Science & Technology)

Oil reservoir simulation is quite difficult due to the discontinuity of material coefficients and the high nonlinearities of the operators. We apply a Newton type method with analytic Jacobian to solve the discretized problem and the linear Jacobian solver is based on a scalable overlapping domain decomposition method. Large scale numerical experiments show that the method is scalable for 3D problems with tens of millions degrees of freedom on a supercomputer with more than 10,000 cores.

Model of Compressible Iimmiscible Fluid with General Navier Boundary Condition

Xiaoding Shi(施小丁) (Beijing University of Chemical Technology)

In this talk, we focus on the gas-liquid phase transition represented by a diffuse interface model. This model is composed of the compressible Navier-Stokes system and a modified Allen-Cahn equation. The generalized Navier boundary condition and the relaxation boundary condition are established in order to solve the problem of moving contact lines on the solid boundary by using the principle of minimum energy dissipation. The local existence and uniqueness of strong solution in three dimensional bounded domain for this type of boundary value problem is proved. Moreover, the sharp interface limit is derived. The proofs are given by the elementary energy method, the maximum principle and by the method of matched asymptotic expansion, but with some technique to establish the uniform bounds of the density.

A data-driven approach for interface motions

Dong Wang(王东) (The University of Utah)

In this talk, we present a framework for approximating unknown interface motions using observation data and deep neural networks. In particular, we consider that the interface is implicitly represented by characteristic functions. Then, we apply the neural networks to predict the interface motion from the observation data. The data needed are only pairs of the initial condition and interface position after one time step. Several numerical experiments will be presented to demonstrate the performance of the method.

Numerical methods for solid-state dewetting problems

Yan Wang(王燕) (Central China Normal University)

This talk is devoted to numerical methods for solid-state dewetting of thin films. Solid-state dewetting belongs to a class of interface problems and the motion of the (film/vapor) interface is governed by surface diffusion and contact line migration. We first review several methods for solving its sharp-interface model, including the “Marker- Particle” method and the parametric finite element method. Then we propose a new approach which can both reduce the stiffness from surface diffusion and improve the performance in mesh equidistribution.This is a joint work with Prof. Wei Jiang and Dr. Weijie Huang.

Extended HDG methods for second order elliptic interface problems

Xiaoping Xie(谢小平) (Sichuan University)

In this talk, we discuss two arbitrary order eXtended hybridizable discontinuous Galerkin (X-HDG) methods for second order elliptic interface problems in two and three dimensions. The first X-HDG method applies to any piecewise C^2 smooth interface. It uses piecewise polynomials of degrees k $(k\geq 1)$ and $k-1$ respectively for the potential and flux approximations in the interior of elements inside the subdomains, and piecewise polynomials of degree k for the numerical traces of potential on the inter-element boundaries inside the subdomains. Double value numerical traces on the parts of interface inside elements are adopted to deal with the jump condition. The second X-HDG method is a modified version of the first one and applies to any fold line/plane interface, which uses piecewise polynomials of degree $k-1$ for the numerical traces of potential. The X-HDG methods are of the local elimination property, then lead to reduced systems which only involve the unknowns of numerical traces of potential on the inter-element boundaries and the interface. Optimal error estimates are derived for the flux approximation in L^2 norm and for the potential approximation in piecewise H^1 seminorm without requiring ``sufficiently large” stabilization parameters in the schemes. In addition, error estimation for the potential approximation in L^2 norm is performed using dual arguments. Finally, we provide several numerical examples to verify the theoretical results. This is joint work with Huangxin Chen， Yihui Han, and Xiao-Ping Wang.

An improved SPH method for simulating 3D dam-break flows with breaking waves

Xiaoyang Xu(许晓阳) (Shaanxi University of Technology)

The numerical simulations of larger-deformation free surface flows are always a hot issue in the field of computational fluid dynamics. Traditional grid-based numerical methods have been employed for the simulations of such flows. However, they require some extra techniques (e.g. VOF, MAC, and Level Set) to track the free surfaces, and the procedure is complicated. In this presentation, I will give an introduction of smoothed particle hydrodynamics (SPH) and show the applications of the method to dam-break flows with breaking waves.

Dynamics of evaporating thin film: phase field modeling and simulations

Xinpeng Xu(徐新鹏) (Guangdong Technion - Israel Institute of Technology)

Many soft matter systems exist as solutions, e.g., polymer solutions and colloidal suspensions. Solutions are made by dissolving a material in a liquid. They usually show fascinating phase structure and dynamic properties. In this talk, I will show the modeling efforts for thin film of simple binary solutions, polymer solutions, diblock copolymer solutions, and colloidal suspensions, in which the solvent is evaporating in a controlled manner. The idea of two-fluid model formulated by Onsager’s variational principle will be the key to the modeling of these different evaporating thin films of soft matter solutions. Some simulations results will also be shown during the talk.

An Analysis of Time-Fractional Allen-Cahn Equations

Jiang Yang(杨将) (Southern University of Science and Technology)

In this work, we consider a time-fractional Allen-Cahn equation, where the conventional time derivative is replaced with a Caputo fractional derivative. First, the well-posedness and (limited) smoothing property are systematically analyzed. Second, after discretizing the fractional derivative by backward Euler convolution quadrature, we develop several unconditionally solvable and stable time stepping schemes, i.e., convex splitting (CS) scheme, weighted convex splitting (WCS) scheme and linear weighted stabilized (LWS) scheme. Meanwhile, we study the discrete energy dissipation property (in a weighted average sense), which is important for gradient flow type models, for the two weighted schemes. Finally, we prove that the convergence rates of those time-stepping schemes are $O(\tau^\alpha)$ without any extra regularity assumption on the solution. We also present extensive numerical results to support our theoretical findings.

Numerical methods for the study of transition events in fluctuating hydrodynamics

Wenqi Yao(姚文琪) (South China University of Technology)

In this paper,we consider transition events between metastable states in fluid systems modeled by two-phase Navier-Stokes equations with thermal noise. Liquid-vapor phase transition, such as the condensation of vapor into liquid droplet, is such an example. We propose a numerical method to compute the transition mechanism.We first approximate the continuum hydrodynamics model by the smoothed particle hydrodynamics (SPH). In the SPH formulation, the dynamics takes the form of Langevin equations, which allow us to derive conditions for the maximum likehood transition path. Then we solve these conditions thereby compute the transition pathway in the space of mass and momentum density fields using the string method.The force, which is needed to evolve the string, is computed in the smoothed particle formulation then transformed back to the space of mass and density fields. This requires the reconstruction of particles consistent with the field description at each time step.The numerical method is illustrated by using the example of the condensation of vapor in equilibrium conditions.

Analysis on the potential theory based Cartesian grid method for interface problems

Wenjun Ying(应文俊) (Shanghai JiaoTong University)

In the past years, we have been working on a potential theory based Cartesian grid method for interface problems. The method solves interface problems on irregular domains with Cartesian grids. It takes advantages of fast elliptic solvers on Cartesian grids and well-conditioning properties of reformulated boundary integral equations. In this talk, I will present some theoretical results on the potential theory based Cartesian grid method for interface problems of the Poisson equation and Stokes equations. Analysis on both stability and accuracy of the method are considered.

Modeling and simulation of an active swimmer in nematic liquid crystal

Lei Zhang(张镭) (Shanghai JiaoTong University)

Living liquid crystal (LLC) is a class of active matter that combines active particles such as swimming bacteria with a lyotropic liquid crystal. The interaction of active motion with orientation order of liquid crystal (LC) leads to striking optical, hydrodynamical, and electrical properties of LLC, as well as collective behavior and emergence of intriguing patterns. In this work, we aim to understand how the orientation order of liquid crystal affects the motion of a single swimmer. We study a nonlinearly coupled PDE model which combines the well-known Edwards-Beris model for liquid crystal hydrodynamics with a squirmer model describing active swimmer. Numerical results show how the anchoring and force dipole strengths affect the stable squirming direction. This is a joint work with Hai Chi, Leonid Berlyand, and Igor Aronson.

MARS: An Analytic and Computational Framework for Incompressible Flows with Moving Boundaries

Qinghai Zhang(张庆海) (Zhejiang University)

Current methods such as VOF methods, level-set methods, and phase-field methods avoid geometry and topology by converting them into problems of numerical PDEs. In comparison, we try to tackle geometric and topological problems with tools in geometry and topology. As the first part of our MARS framework, we propose a topological space called the Yin space as a mathematical model for physically meaningful material regions. Each element in the Yin space is a regular open semianalytic set with bounded boundaries. We further equip the Yin space with Boolean algebra so that the topology info (such as the Betti numbers of a material region) can be extracted in constant time. In particular, non-manifold points on the fluid boundary, a key problem in studying topological changes, are handled naturally. The second part of MARS is the donating region theory in the context of hyperbolic conservation laws. For a fixed simple curve in a nonautonomous flow, the fluxing index of a passively advected Lagrangian particle is the total number of times it goes across the curve within a given time interval. Such indices naturally induce donating regions, equivalence classes of the particles at the initial time. Under the MARS framework, many explicit methods such as VOF methods and fronting tracking methods can be unified and proved to be second-order accurate. MARS also leads to new methods of fourth- and higher-order accuracy for interface tracking and curvature estimation. The MARS framework can be further expanded with a fourth-order projection method called GePUP for numerically solving the incompressible Navier-Stokes equations (INSE). We have augmented GePUP to irregular domains and are currently working on coupling GePUP with our new interface tracking methods to form a fourth-order solver for INSE with moving boundaries.

A hybrid asymptotic and augmented compact FVM for nonlinear singular differential equation and its application in the interface problem

Zhiyue Zhang(张志跃) (Nanjing Normal University)

An accurate and efficient numerical method has been proposed for nonlinear singular two points boundary value problem. The scheme combines Puiseux series asymptotic technique with augmented fourth order compact finite volume method for the problem. Error estimates in different norms are obtained. Numerical examples confirm the theoretical analysis and efficiency of the method. We also apply this method for solving singular interface problem, numerical experiments show that the method works well for solving the interface problem.

Phase Field Model of Cell Migration

Yanxiang Zhao(赵雁翔)(George Washington University)

We propose a model for the morphology and dynamics of a crawling eukaryotic cell to describe cells on micro patterned substrates. This model couples cell morphology, adhesion, and cytoskeletal flow in response to active stresses induced by actin and myosin. We propose that protrusive stresses are only generated where the cells adhere, leading to the effective confinement to the pattern. Simulated cells exhibit a broad range of behaviors, including steady motion, turning, bipedal motion and periodic migration. We further extensively study the turning instability by simplifying the full PDE model into a minimal one. By using the minimal model, we also study the persistent rotational motion (PRM) of small numbers of mammalian cells crawling on micropatterned substrates.

4.Participants List

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