



Workshop on Mathematical and Mechanical Design of New Materials

1. Event Schedule

Registration and check-in: June 07, 2026 Sunday; Check-out: June 13, 2026 (or June 14) Saturday (Sunday); Talks and discussions: June 08, 2026-June 12, 2026

Conference schedule

Registration and check-in: June 07, 2026 (Sunday) Breakfast: 7:30-9:00

June 08, 2026 (Monday)		
Time	Speaker	Title
8:50-9:00	Welcome and Opening Remarks	
9:00-9:50	John Ball	Rank-one connections and microstructure in single crystals and polycrystals
9:50-10:10	Tea/Coffee break	
10:10-11:00	Sherry Chen	A Mechanics-Guided Roadmap for Phase-Transforming Alloys to Achieve Million-Cycle Reversibility
11:30-14:00	Lunch break	
14:00-14:50	Weiqiu Chen	Potential theory method for mechanics problems with multi-field couplings and its applications
14:50-15:10	Tea/Coffee break	
15:10-16:00	Pingbing Ming	Deep learning methods for large plate bending
16:00-16:50	Haigang Li	Conductivity Problems with Imperfect Low-conductivity Interfaces
17:30-19:00	Dinner	

June 09, 2026 (Tuesday)		
Time	Speaker	Title
9:00-9:50	David Srolovitz	Grain Boundary Migration and Grain Growth: recent progress and open questions
9:50-10:10	Group Photo and Tea/Coffee break	
10:10-11:00	Tomonari Inamura	Geometric compatibility and suppression of defect accumulation in martensitic transformations
11:30-14:00	Lunch break	
14:00-14:50	Jinhae Park	TBD
14:50-15:40	Jie Xu	Quasi-entropy: in free energies and closure approximations

15:40-16:00	Tea/Coffee break	
16:00-16:50	Shuo Yang	Convergent finite element method for liquid crystal polymer networks
17:30-19:00	Dinner	

June 10, 2026 (Wednesday)		
Time	Speaker	Title
9:00-9:50	Antonio DeSimone	Biophysics of motility of unicellular organisms
9:50-10:10	Tea/Coffee break	
10:10-11:00	Chaozhen Wei	Continuum modeling of bio-chemo-mechanical coupling in growing tissues
11:30-13:00	Lunch break	
13:00-18:00	Free Discussions/ Excursion	
18:00-19:00	Dinner	

June 11, 2026 (Thursday)		
Time	Speaker	Title
9:00-9:50	Ning Jiang	TBD
9:50-10:10	Tea/Coffee break	
10:10-11:00	Tianyu Yuan	Effective long-time diffusivity of irregular particles in an external field
11:00-14:00	Lunch break	
14:00-14:50	Changqing Chen	Static topological mechanics
14:50-15:40	Isaac Chenchiah	Multiphase architected materials and morphing structures
15:40-16:00	Tea/Coffee break	
16:00-16:50	Mingjian Wen	Theory of irreducible Cartesian tensors and applications to atomistic machine learning
17:30-19:00	Dinner	

June 12, 2026 (Friday)		
Time	Speaker	Title
9:00-9:50	Yongzhong Huo	Soft, Semi-soft and Anisotropic-soft Elastic Behavior in Liquid Crystal Elastomers
9:50-10:10	Tea/Coffee break	
10:10-11:00	Rui Zhang	Hydrodynamic simulations of topological defects in nematic liquid crystals
11:30-14:00	Lunch break	
14:00-14:50	Xudong Liang	Modelling and Design of Monodomain Liquid Crystal Elastomers

14:50-15:40	Ju Chen	Geometric Mechanics Modeling, Computation, and Control of Constrained Dynamical Systems
15:40-16:00	Tea/Coffee break	
16:00-16:50	Fan Feng	Geometric compatibility guided design of new materials and structures
17:30-19:00	Dinner	

2. Location

TYMC, Yiliang County, Kunming City, Yunnan Province, P.R.China.

3. Important Notice

1. This seminar is sponsored by the TYMC. Accommodation and meals for all participants will be covered by the Center, while other expenses shall be on the participants themselves. No registration fee is needed.
2. The shuttle buses running between the TYMC and the airports/railway stations are available for free reservation. All participants are requested to register in advance.
3. Night driving is strongly discouraged. Mountain roads require experienced driving skills.
4. The center is approximately a 40-minute drive from Gucheng Town Central Health Center, about a 1-hour drive from Yiliang County People's Hospital, and about a 1-hour drive from Shilin Yi Autonomous County People's Hospital. It is advisable to carry some essential medicines with you at all times. For medical emergencies, the center keeps a stock of commonly used medicines, including those for mosquito bites, 999 Ganmaoling Granules, Lianhua Qingwen Capsules, Yunnan Baiyao Spray, and bandages.
5. More information can be found at: <http://tianyuan.amss.ac.cn/en/>

4. Organisers

Fan Feng/冯帆 (Peking University)

Xian Chen/陈弦 (Hong Kong University of Science and Technology)

John Ball (Heriot-Watt University)

5. Invited Attendee

Name	Affiliation	Research Area
John Ball	Heriot-Watt University	Mathematics
Sherry Xian Chen/陈弦	Hong Kong University of Science and Technology	Solid mechanics/Materials

Weiqliu Chen/陈伟球	Zhejiang University	Solid mechanics
Tianyu Yuan/袁天宇	Chengdu University	Solid mechanics
Jie Xu/徐劼	Institute of Mathematics and Systems Science, CAS	Applied mathematics/Liquid crystals
Jinhae Park	Chungnam National University	Liquid crystal/Applied math
Yongzhong Huo/霍永忠	Fudan University	Solid mechanics
Xudong Liang/梁旭东	Harbin Institute of Technology (Shen Zhen)	Solid mechanics
Shuo Yang/杨朔	Beijing Institute of Mathematical Sciences and Applications	Applied mathematics
Ning Jiang/江宁	Wuhan University	PDE
Rui Zhang/张锐	Hong Kong University of Science and Technology	Liquid crystals
Changqing Chen/陈常青	Tsinghua University	Solid mechanics/metamaterials
Pingbing Ming/明平兵	Institute of Mathematics and Systems Science, CAS	Applied mathematics
Fan Feng/冯帆	Peking University	Solid mechanics/materials
Tomonari Inamura	Tokyo Institute of Technology	Solid mechanics
Ju Chen/陈菊	Beijing Institute of Technology	Geometric mechanics
David J. Srolovitz	Hong Kong University	Materials/Mechanics
Haigang Li/李海刚	Beijing Normal University	PDEs/Mathematical materials
Antonio DeSimone	SISSA	Mechanics/Applied math
Chaozhen Wei/魏朝祯	University of Electronic Science and Technology of China	Applied mathematics/Bio mechanics
Isaac Chenchiah	University of Bristol	Solid mechanics/Applied math
Liping Liu/刘利平	Rutgers University	Solid mechanics
Linjuan Wang/王林娟	Beihang University	Solid mechanics
Mingjian Wen/文明健	University of Electronic Science and Technology of China	Solid mechanics
Sheng Mao/毛晟	Peking University	Solid mechanics
Hanlin Gu/谷翰霖	Peking University	Solid mechanics
Donghao Li/李东昊	Peking University	Solid mechanics

Rank-one connections and microstructure in single crystals and polycrystals

John BALL

Department of Mathematics, Heriot-Watt University and Maxwell Institute for Mathematical Sciences, Edinburgh and Hong Kong Institute for Advanced Study

Abstract: The talk will describe how nonlinear elasticity can be used to predict microstructure arising from solid phase transformations in alloys, and survey some recent results related by the common theme of finding rank-one connections between energy wells, these describing possible planar interfaces between different phases. The results concern slip and twinning in Bravais lattices, compatibility of martensitic microstructures across polycrystal grain boundaries, and remarkable martensitic microstructures observed in the alloy Ti76Nb22Al2.

A Mechanics-Guided Roadmap for Phase-Transforming Alloys to Achieve Million-Cycle Reversibility

Sherry CHEN

Hong Kong University of Science and Technology

Abstract: Functional materials capable of stress-induced martensitic phase transformations are central to technologies spanning biomedical devices, microelectronics, and energy systems. A key requirement for their long-term reliability is the ability to undergo fully reversible transformations under repeated mechanical cycling. In this talk, I will present recent breakthroughs in understanding the fatigue behavior of such materials via micropillar mechanics tests. We theorized that reversibility is not the privilege of a single "perfect" alloy, but can be achieved across different levels of crystallographic compatibility through distinct mechanisms. In alloy systems satisfying the Cofactor Conditions [4], single-crystal micropillars sustain over 10 million transformation cycles with minimal energy dissipation and no structural degradation [2]. In polycrystalline systems that do not meet such stringent crystallographic criteria, tailored grain boundary compatibility can nonetheless suppress defect accumulation and deliver reversible superelastic behavior [1], while the two-tier compatibility framework rationalizes how bi-crystal interfaces accommodate transformation strain without localized failure [3]. Together, these findings pave a mechanics-guided route along which crystallographic, interfacial, and microstructural design offer complementary paths to ultra-durable functional devices at small scales.

References:

[1] M. Karami, P. A. Carvalho, A. E. Gunnæs, O. M. Løvvik, X. Chen, "Grain Boundary Compatibility and Its Impact on the Reversibility of Superelastic Micropillars," *J. Mech. Phys. Solids* 205, 106309 (2025).

[2] M. Karami, Z. Zhu, K. H. Chan, P. Hua, N. Tamura, X. Chen, "Non-dissipative martensitic phase transformation after multi-million superelastic cycles," *Phys. Rev. Lett.* 132, 066101 (2024).

[3] M. Karami, Z. Zhu, Z. Zeng, N. Tamura, Y. Yang, X. Chen, "Two-tier compatibility of Superelastic Bi-crystal Micropillar at Grain Boundary," *Nano Letters* 20(11), 8332 (2020). ACS Editor's Choice Article.

[4] Y. Song, X. Chen, V. Dabade, T. W. Shield, R. D. James, "Enhanced reversibility and unusual microstructure of a phase-transforming material," *Nature* 502, 85 (2013).

Potential theory method for mechanics problems with multi-field couplings and its applications

Weiqiu CHEN

Zhejiang University

Abstract: Significant progress has been made in mixed boundary-value problems associated with three-dimensional (3D) crack and contact analyses of advanced materials featuring more complexities as compared to the conventional isotropic elastic materials. These include material anisotropy and multi-field coupling, two typical characteristics of most advanced multifunctional materials. Here we try to present a state-of-the-art description of 3D exact/analytical solutions derived for crack and contact problems of elastic solids with both transverse isotropy and multi-field coupling in the recent decades by the potential theory method in the spirit of V. I. Fabrikant, whose ingenious breakthrough brings new vigor and vitality into the old research subject of classical potential theory. We are particularly interested in crack and contact problems with certain nonlinear features. Emphasis is also placed on the coupling between the temperature field (or the like) and other physical fields (e.g. the elastic, electric and magnetic fields). We further highlight the practical significance of 3D contact solutions, in particular in applications related to modern scanning probe microscopes.

Deep learning methods for large plate bending

Pingbing MING

Institute of Mathematics and Systems Science, CAS

Abstract: We propose a deep learning based method for simulating the large bending deformation of bilayer plates with or without prestrain. Inspired by the greedy algorithm, we propose a pre-training method on a series of nested domains, which accelerate the convergence of training and find the global minimizer more effectively. The proposed method exhibits the capability to converge to an absolute minimizer, overcoming the limitation of gradient flow methods getting trapped in the local minimizer basins. We showcase better performance with fewer numbers of degrees of freedom for the relative energy errors and relative L2-errors of the minimizer through numerical experiments. As to the plate with prestrain, we propose a new

loss functional and a new network structure to ensure the constraints can be preserved, which is crucial for the method to find the global minimizer.

Conductivity Problems with Imperfect Low-conductivity Interfaces

Haigang LI

Beijing Normal University

Abstract: In composites, stress concentrates dramatically between inclusions as their separation distance $\epsilon \rightarrow 0$. In practice, interfaces are often imperfect due to delamination or coating, and are typically modeled by Robin boundary conditions. In this talk, we study field concentration between two nearly touching conductors separated by such imperfect interfaces and establish optimal pointwise gradient estimates that depend explicitly on both γ and ϵ , thereby unifying the bounded regime ($\gamma > 0$) and the singular blow-up case ($\gamma = 0$) into a continuous characterization of the transition as interface quality degrades.

Grain Boundary Migration and Grain Growth: recent progress and open questions

David SROLOVITZ

Hong Kong University

Abstract: In the 1940s and '50s CS Smith suggested that grain growth in polycrystalline materials is analogous to the coarsening of soap froths; i.e., grain boundary (GB) mean curvature flow. In 1952, von Neumann proposed a law that showed that the rate of growth of an individual grain scales with its number of sides, n , as $(n-6)$ in 2-dimensions; i.e., purely topological. Mullins showed that this follows from the Gauss-Bonnet theorem; unfortunately, extensions to higher dimensions do not. MacPherson and I derived an exact relation for the growth of a grain in all dimensions (von Neumann-Mullins is a special case). That seemed to have solved the problem. However, recent work (experiment and simulation) has shown that the initial premise, grain growth is purely mean curvature flows, is inadequate to describe grain growth. The physics is now much clearer - GBs move by the motion of line defects (disconnections) constrained to the GB plane that carry both steps and mechanical deformation (dislocation-like) Zhang, Han, Xiang and I proposed an alternative, GB equation of motion. A body of experimental evidence and atomistic simulation show that these ideas are sound, but many questions still remain. This talk will review the background, summarize the current state of our understanding of grain growth and pose a set of outstanding problems for consideration.

Geometric compatibility and suppression of defect accumulation in martensitic transformations

Tomonari INAMURA

Laboratory for Materials and Structures, Institute of Integrated Research, Institute of Science
Tokyo

Abstract: Dislocation accumulation during martensitic transformations is one of the major origins of functional degradation in shape memory alloys. In Ti–Ni-based alloys, transformation interfaces often develop zigzag habit planes, which are closely associated with the accommodation of local incompatibility and the introduction of dislocations. In this talk, I present recent results based on the concept of triplet compatibility from the viewpoint that eliminating such incompatibility-accommodating structures may suppress dislocation accumulation. Triplet compatibility is a collective compatibility condition among three martensitic variants and does not consider compatibility between martensite and the parent phase at all. Nevertheless, Ti–Ni-based alloys satisfying this condition form highly compatible mosaic-like microstructures and exhibit remarkably suppressed dislocation accumulation even after repeated transformation cycles. These results suggest that complete parent–martensite compatibility, such as the cofactor condition, is not the only mechanism for suppressing dislocation introduction. Instead, martensitic variants may avoid incompatibility-accommodating structures themselves by forming lower-energy microstructures.

TBD

Jinhae PARK

Chungnam National University

Quasi-entropy: in free energies and closure approximations

Jie XU

Institute of Mathematics and Systems Science, CAS

Abstract: Molecular-theory-based tensor models of liquid crystals typically contain an explicit entropy term deduced from the maximum entropy state. For dynamic models, high-order tensors also appear in the model, for which a classical closure approximation is also given the maximum entropy state. The maximum entropy state is able to maintain the essential properties and structures of the molecular theory in tensor models, but leads to high computational cost. Quasi-entropy is a class of elementary functions to substitute the terms deduced from the maximum entropy state, which can be incorporated both in free energies and in closure approximations. It not only keeps the desired properties and structures of the models, but also reduces the complexity of dealing with implicit functions involving three dimensional integrals to $O(1)$. We present a few representative results in equilibrium states and dynamics.

Convergent finite element method for liquid crystal polymer networks

Shuo YANG

Beijing Institute of Mathematical Sciences and Applications (BIMSA)

Abstract: Liquid crystal polymer networks (LCN) deform spontaneously upon temperature or optical actuation. This property can be exploited in the design of materials to achieve non-trivial shapes. These materials combine the features of rubber and nematic liquid crystals. In this work, we first derive a 2D membrane model from 3D neo-Hookean elasticity via formal asymptotics, where the obtained limiting model and the derivation are inspired by Virga et al., Bhattacharya et al. and Cirak et al. The membrane model consists of a minimization problem of a non-convex energy functional for deformations of the materials, and the equilibrium shapes depend on the design of blueprinted nematic orders and pre-determined actuation parameters. We discuss properties of this energy functional and its global minimizers. We design a finite element discretization for this model, propose a novel iterative scheme to solve the non-convex discrete minimization problem, and prove stability of the scheme and a convergence of discrete minimizers. We present a wide range of numerical simulations to illustrate effectiveness and efficiency of our algorithm, as well as the fact that this model captures quite rich physical phenomenon. These simulations include some results of practical interests that matches lab experiments, the design of origami shapes and a quantitative study of our numerical method.

Biophysics of motility of unicellular organisms

Antonio DESIMONE

Scuola Internazionale Superiore di Studi Avanzati (SISSA)

Abstract. Active matter is a broad field with many potential applications. A common thread underlying many of the current research lines is the study of systems powered by some internal energy source, as in the case of organisms moving thanks to food metabolism. In fact, self-propelling systems need to overcome the resistance of the surrounding medium, drawing the required energy from internal sources. The study of locomotion and self-propulsion in biological and bio-inspired artificial system appears, therefore, as an ideal testing ground to put the concepts and tools of active matter at work.

We will report on recent progress coming from case-studies on the motility and collective feeding of unicellular organisms (flagellates and ciliates) and bio-inspired micro-robots, studied from the point of view of the mechanics of active matter.

Continuum modeling of bio-chemo-mechanical coupling in growing tissues

Chaozhen WEI

University of Electronic Science and Technology of China

The inhomogeneity of cell proliferation, apoptosis, and myosin-dependent contraction can generate elastic stress and strain in living tissues, which may be dissipated by internal

rearrangement through cell topological transition and cytoskeletal reorganization. Moreover, cells and tissues can change their sizes in response to mechanical cues. We propose a framework for the chemomechanical regulation of growth based on thermodynamics of continua and growth-elasticity to predict growth patterns. Combining the elastic and chemical energies, we use an energy variational approach to derive a novel formulation that isolates the mass-conserving tissue rearrangement from the mass-accretion volumetric growth, and incorporates independent energy-dissipating stress relaxation and biochemomechanical regulation of the volumetric growth rate respectively. We apply the model to study the tissue growth and mechanics in the context of differential growth induced by the growth-promoting factor field undergoing a reaction-diffusion process. We aim to demonstrate the roles of the tissue material properties and mechanical feedback regimes on its growth and mechanical regulation.

TBD

Ning JIANG

Wuhan University

Effective long-time diffusivity of irregular particles in an external field

Tianyu YUAN

Chengdu University

Abstract: The diffusion of irregular particles with anisotropic mobility often involves coupled Brownian motion in position-orientation space, going beyond the classical Stokes–Einstein relation. This talk presents a multiscale theoretical framework for deriving the effective long-time translational diffusivity of arbitrarily shaped rigid particles in Stokes flow under an external orienting field. Starting from stochastic dynamics and proceeding through multiscale analysis, the effective diffusivity is characterized through a unit-cell problem on the orientation space, together with variational formulations, rigorous bounds, and exact limiting solutions. The theory clarifies the reference-point independence of the effective diffusivity and provides a basis for understanding field-regulated transport in complex materials.

Static topological mechanics

Changqing CHEN

Tsinghua University

Abstract: Topological mechanics, aiming to explore topological insulator-like anomalous and robust edge channels of wave propagation in mechanical systems, is based on wave dynamics. We demonstrate that dynamic phonons are not the only elementary excitations in topological

mechanics; topology is also inherent in static load-induced deformations of mechanical metamaterials and elastic continua. We introduce the concept of static topological mechanics, leveraging the space-time duality and imaginary gauge transformation between static and associated wave dynamic systems. In static and time/frequency-independent systems, topologically nontrivial modes manifest as static deformations localized at boundaries or interfaces. These robust topological properties can be used to effectively regulate localized deformations resistant to structural disorders and defects, such as creating multi-directional stress guides in static lattice materials. Several paradigmatic topological states in static mechanical metamaterials, including topological zero modes, multipole higher-order topologies, and non-Hermitian topologies, are outlined. We also discuss future challenges and opportunities in static topological mechanics.

Multiphase architected materials and morphing structures

Isaac CHENCHIAH

School of Mathematics, University of Bristol

Abstract. We investigate a class of architected materials inspired by multiphase solids: triangular lattices with multistable edges. These can also be viewed as multistable or morphing structures, i.e., structures that can change their shape in response to their environment. A medical implant that adapts as a patient grows or ages, reducing the need for additional surgical interventions, is an example. Despite its immense technological potential, this area of contemporary engineering research has received surprisingly little mathematical attention.

This talk explores a broad class of architected multiphase materials / morphing structures: planar triangular frameworks with multi-stable edges. We examine their equilibrium states; characterise all hexagonal shapes, including those with an annulus; and explore the effects of boundary conditions. We show how our results lead to efficient non-numerical algorithms to compute the equilibrium states of such architected multiphase materials / morphing structures.

Theory of irreducible Cartesian tensors and applications to atomistic machine learning

Mingjian WEN

University of Electronic Science and Technology of China

Abstract: Tensors are the natural language of materials science: stress, strain, elasticity, and many other properties are tensorial in nature, constrained by the symmetries of space and of the underlying crystal. A key question is how an arbitrary tensor decomposes into its fundamental, symmetry-irreducible pieces, the parts that transform independently under symmetry groups like $SO(3)$. While this is classically handled through spherical-harmonic

machinery, there is a compelling motivation for working directly in Cartesian coordinates, the form in which materials and their properties are most naturally described.

In this talk, I will present irreducible Cartesian tensors built on the concept of natural tensors: intrinsic geometric objects determined by the structure of the space they inhabit. I will show how this yields a systematic scheme for decomposing and reconstructing high-rank physical tensors, while respecting their intrinsic symmetries. I will also discuss how this becomes a powerful tool for atomistic machine learning, naturally embedding geometric equivariance into data-driven predictions of material behavior at the atomic scale---from interatomic interactions across the periodic table to physical properties ranging from dipole moments to elastic constant tensors.

Soft, Semi-soft and Anisotropic-soft Elastic Behavior in Liquid Crystal Elastomers

Yongzhong HUO

Fudan University

Abstract: Liquid crystal elastomers (LCEs) are weakly crosslinked polymer materials with liquid crystal moieties. Soft elasticity has been predicted for nematic elastomers due to broken symmetry in the isotropic-nematic phase transition. A vanishing shear modulus and a very low stress plateau are the typical soft behavior of monodomain nematic LCEs. Although stress plateaus due to the director rotation are often observed in experiments, the critical stresses and strains are generally not very small. And the shear modulus is not small either. Moreover, the elastic modulus parallel to the director can be much larger than the perpendicular modulus.

The neo-classical model based on the Trace formula and a semisoft energy correction has been widely used to model the semisoft elasticity of LCEs. Adopting its strain decomposition, a generic soft elastic strain energy function can be constructed to have anisotropic elastic moduli that well agree with the experiments. Possible higher order energy penalties for the director rotations are introduced and their effect on the director rotations is discussed. Finally, we consider the effect of the anisotropic elastic moduli on the soft behavior. By using the analytic solutions in linear elasticity, we found that almost all reported LCEs have two interesting characters, 1) the effective modulus under oblique stretching can be smaller than the parallel and perpendicular moduli; 2) the strain concentration sites at the edge of a circular hole do not coincide with the stress concentration. Both characters are closely related to the stress-induced director rotations and might be considered as indications of soft elasticity.

Hydrodynamic simulations of topological defects in nematic liquid crystals

Rui ZHANG

Hong Kong University of Science and Technology

Abstract. Nematic liquid crystals (LCs) are a type of complex fluid whose microstructure is highly sensitive to external stimuli, including electromagnetic fields, mechanical strains, heat, and other nonequilibrium processes. Nematic LCs have been widely studied for their applications in displays, electro-optic devices, and biosensors. In recent decades, there has been growing interest in investigating dynamic phenomena in nontraditional LCs, such as active nematics, nematic LC colloids, and ferroelectric nematic LCs. The viscoelastic nature of nematics, the coexistence of multiple components, and the nonequilibrium processes involved pose significant challenges to theorists. In this talk, I will discuss state-of-the-art simulation methods for modeling the hydrodynamic flows of nematic liquid crystals. In particular, I will focus on the behavior of topological defects in flowing nematics. These research efforts reveal a previously overlooked connection between flowing nematics and solid mechanics, and our simulation framework has proven successful in explaining and predicting a range of experimental observations.

Modelling and Design of Monodomain Liquid Crystal Elastomers

Xudong LIANG

Harbin Institute of Technology (Shen Zhen)

Abstract: Liquid crystal elastomers are active soft materials that couple liquid-crystal ordering with large deformation of polymer networks. Their macroscopic actuation is governed by the interaction among temperature, mechanical deformation, and the evolution of molecular order. In this talk, I will present a thermo-mechano-order coupled constitutive framework for monodomain liquid crystal elastomers. The model treats the scalar order parameter as an internal variable and formulates the anisotropic elastic response, thermal spontaneous deformation, and order-parameter evolution within a thermodynamically consistent finite-deformation framework. The governing equations are numerically discretized and implemented into ABAQUS, enabling finite element simulation of coupled actuation processes.

Based on this modeling framework, two classes of LCE structures are designed. The first is a bilayer LCE shell, where the mismatch of thermal response across the thickness converts anisotropic spontaneous deformation into curvature change and rapid snap-through instability. The second is a bioinspired artificial muscle, where soft elasticity and thermally induced spontaneous deformation are used as two distinct mechanical mechanisms to enable independent regulation of stiffness and actuation deformation. For both systems, the proposed model serves as a quantitative design tool to reveal the underlying deformation mechanisms and establish design criteria. This work provides a mechanics framework that connects constitutive modeling, numerical simulation, and structural design, offering a route toward programmable soft material systems with tailored actuation, stiffness, and instability.

Geometric Mechanics Modeling, Computation, and Control of Constrained Dynamical Systems

Ju CHEN

Beijing Institute of Technology

Abstract: To address the demands of on-orbit assembly, complex environment exploration, and related applications, there is an urgent need for efficient geometric modeling, structure-preserving computation, and control methods for complex constrained dynamical systems. In recent years, computational geometric mechanics and geometric control, developed from modern differential geometry and Lie group/Lie algebra theory, have provided unified frameworks for the modeling, computation, and control of constrained dynamical systems. Their key features include extending traditional local analyses to global analyses on manifolds, revealing intrinsic geometric structures and symmetries, and developing geometric integrators capable of preserving geometric structures and conservation laws over long-time simulations. By integrating nonlinear control theory with geometric mechanics, geometric control theory enables globally consistent stability analysis and control on manifolds, leading to control strategies with large domains of attraction, strong robustness, and structure-preserving properties.

However, significant challenges remain in the unified modeling, computation, and control of high-degree-of-freedom finite-dimensional constrained systems and infinite-dimensional continuum systems. Under large deformations and rotations, traditional approaches struggle to achieve globally consistent and singularity-free geometric descriptions while maintaining unified compatibility among geometrically exact beam, plate, and shell models. Conventional finite element methods are prone to numerical pathologies such as shear locking, making it difficult to simultaneously achieve high-order accuracy, computational efficiency, and long-time energy-momentum preservation. Furthermore, strong nonlinearities, momentum coupling, and nonholonomic constraints lead to highly coupled dynamical equations and high computational complexity, limiting the real-time control and online identification of complex flexible systems.

Within the framework of geometric mechanics, this report establishes globally singularity-free descriptions of nonlinear rotational motion, develops high-order geometrically exact finite elements and space-time consistent interpolation schemes, effectively eliminates shear locking, and constructs geometric integrators with long-time structure-preserving properties. Furthermore, under the principal fiber bundle framework, a minimum-dimensional intrinsic dynamical model is developed to achieve analytical decoupling of dynamical coupling terms, significantly reducing system nonlinearities and computational complexity. Future work will investigate dynamical evolution and information transport on probability distribution manifolds, aiming to establish a unified framework integrating information geometry, stochastic dynamics, and geometric control. This framework will enable geometric representations of uncertainty, probabilistic propagation, and stability analysis, providing theoretical foundations for the reliable operation of autonomous intelligent systems, including spacecraft, underwater vehicles, and robots, in complex stochastic environments.

Geometric compatibility guided design of new materials and structures

Fan FENG

Peking University

Abstract: Geometric compatibility, in simple terms, concerns how different shapes fit together in space without discontinuities, and therefore plays a fundamental role in continuum mechanics. In this talk, I will discuss how geometric compatibility, understood in a broad sense, can guide the rational design of new materials and structures. Particular examples include phase-transforming materials with unusual symmetries, anomalous mechanical responses in liquid crystal elastomers, and Euclidean/non-Euclidean origami structures. Some open problems for consideration will also be discussed.