Biomimetics: Innovative Engineering based on Biodiversity and Self-Organization

Masatsugu Shimomura
(Professor, Chitose Institute of Science and Technology,
Professor Emeritus, Hokkaido University and Tohoku University, Japan)

Abstract

Biomimetics is the innovative paradigm shift based on biodiversity for sustainability. Biodiversity is not only the result of evolutionary adaptation but also the optimized solution of “an epic combinatorial chemistry” for sustainable adaptation, because the diversity has been acquired by “biological processes and technology” including “production processes”, “operating principles”, and “control systems”, all of which are based on self-organization of life and ecological system. The comprehensive “technology transfer” from ”biological diversity” to “human wisdom” is indispensable to open the new paradigm. Recent progress of the information science can transform the knowledge of natural history into the information of engineering.

Research area(s): Biomimetics, Nanotechonology, Polymer science

Functionalization of honeycomb-patterned porous polymer films using a reactive vapor in breath figure method

Bo Kyoung Shin and Do Sung Huh*
(Department of Chemistry and Nanoscience and Engineering,
Center for Nanomanufacturing Inje University,
Gimhae city, Gyeongsangnam-do, South Korea)

Abstract

A new strategy is proposed to obtain pore functionalized honeycomb-patterned porous films by in-situ polymerization during breath figure process. The polystyrene or hydrophobic polymers with an initiator such as benzoyl peroxide mixture in chloroform are casted under humid conditions generated by pumping air containing a reactive vapor such as aniline hydrochloride, KOH, etc. in water. The resulting films showed honeycomb-patterned porous morphology with functionalized pores. The formation of functionalized film is confirmed by color, conductivity, SEM, and UV-visible studies, etc. The strategy can be extended to obtain various pore functionalized films by choosing one reactant in polymer solution and other in humid vapors with a facile method of one-step breath figure process.

Research area(s): Functional polymer films

Design of crack morphology using memory of plastic deformation

Akio Nakahara
(Professor, Nihon University, Japan)

Abstract

Morphology of crack patterns can be controlled by using memory of plastic deformation. For example, densely packed colloidal suspension, called paste, remembers direction of its motion such as shear and vibration and, when it is dried, these memories in paste can be visualized as morphology of crack patterns, because directions of crack propagation strongly depend on what kind of memory the paste has.It is shown that plastic deformation of paste plays a key role in memory effect. By imprinting, rewriting and erasing these memories in paste, it becomes possible to design and produce crack patterns as you like.

Research area(s): Physics of Pattern Formation, Crack Formation, Rheology of Softmatter

Recent developments of combinatorial rigidity theory

Naoki Katoh
(Professor, Department of Informatics, Kwansei Gakuin University,
Professor Emeritus, Kyoto University, Japan)

Abstract

Rigidity and stability analysis for discrete structures such as frame structure and linkage is a classical topic in physics and engineering. This is a fundamental topic that appears in advanced research challenges such as modern behavior analysis of molecular framework and robotics, localization of crystal structures. The objective of combinatorial rigidity theory is to clarify combinatorial characterization of discrete structures. This talk introduces the fundamental theory and recent developments of combinatorial rigidity and touches upon modern applications.

Research area(s): Combinatorial optimization, the design and analysis of combinatorial and geometric algorithms

Transcoding Crystals on the search for Extreme in Architecture

Arzu Gönenç Sorguç
(Joint work with Müge KRUSA, Fırat ÖZGENEL)
(Professor, Dr., Vice Dean of the Faculty of Architecture,
Director of METU Design Factory)

Abstract

Biomimetics is an overarching subject breaking up the borders of the disciplines. Biomimetic studies can be interpreted as transcoding of nature into man-made world and one of the major challenges in this process is the diversity of the scale from nano to macro. It is seen that most of the recent biomimetic studies is focused on the animate part of the nature, and studies on inanimate part of it is relatively limited and confined mostly in the silos of material related disciplines

Crystals are extremely interesting and challenging formations of nature in which perfect symmetries in all scales are possible and although they are in-animate they can grow, mutate, evolve, change state but in a way never “die”. Their initial unit cells and lattices in nano scale determines their formations in different scales together with internal and external forces acting on them.

Computational design in broad sense is a relatively new, by-nature, an interdisciplinary field spanning over various subjects. This work is a part of on-going study aiming to explore the re-use of inanimate nature first understanding the formations for which thermodynamic and mechanic forces are the major inputs of the processes.

This part of the present study as a true challenge is concerned to develop a generative computational model/simulation/visualization system for the crystal formation processes in different scales and in different media from mathematical/computational models to 3D fabrication and virtual environments in order to extend the research to transcode formation forces of crystal to mechanical forces of the environment through similitude approach to further discuss new implementations in architecture.

Research area(s): Computational Design, Biomimicry, Fabrication Technologies

Endless forms most beautiful: Iterative self-organization in biology

Robert Sinclair
(Associate Professor, Okinawa Institute of
Science and Technology Graduate University, Japan)

Abstract

The Malthusian struggle for existence infused Darwin's and Wallace's understanding of natural selection, the mechanism by which evolution occurs. This aspect of struggle profoundly shapes self-organisation as observed in living systems, including, for example, programmed cell death. I will provide a number of examples — the enigmatic fairy circles of Namibia, viral factories and virophages, sea squirt metamorphosis and the origin of the starfish's distinct form — all involving replacement or destruction of previous structures, sometimes iteratively, rather than pure hierarchical construction. I wish to emphasize the sometimes overlooked role of destruction in self-organised beauty.

Research area(s): Mathematical biology, Experimental mathematics

Molecular Organization: The Case of Bilayer Membrane

Toyoki Kunitake
Recipient of the "Order of Culture"

(Professor, Institute of Advanced Studies, Kyushu University, Japan)

Abstract

Biomembranes are highly organized molecular systems that execute amazingly complicated functions within the nano-sized domain. We demonstrated that analogous molecular organizations were formed spontaneously from a variety of synthetic amphiphiles, and concluded that spontaneous bilayer assembly is a general physicochemical phenomenon (not limited to the biological system). Such synthetic bilayer membranes are quite convenient for design of novel artificial nanofilms. Typical example includes formation of ordered multilayer films by simple casting and superior molecular recognition via complimentary hydrogen bonding at the air-water interface.

Research area(s): Molecular organization, Bilayer membrane, Nano-film

Stability of fronts in bidomain models

Hiroshi Matano
(Professor, The University of Tokyo, Japan)

Abstract

The bidomain equations are important mathematical models in the study of cardiac electrophysiology. They are used in the numerical emulation of various electrophysiological activities of hearts. Despite their importance in such applications,

very little is known theoretically about the qualitative properties of bidomain models in general. In this talk, I will discuss the stability of fronts arising in the bidomain Allen--Cahn type equations and show some examples in which flat planar fronts collapse in a peculiar manner.

Research area(s): Nonlinear partial differential equations

Voronoi Diagram of Spherical Balls: Properties and Applications

Deok-Soo Kim
(Professor, Department of Mechanical Engineering,
Hanyang University, Seoul, Korea)

Abstract

The beautiful properties of the ordinary Voronoi diagram of points are well-known and diverse types of Voronoi diagrams inherit this beauty if they can be correctly and efficiently constructed. However, there are only a few classes of Voronoi diagrams whose construction methods are well-established. Even the efficient and robust construction of the Voronoi diagram of circular disks in the plane, also known as an additively-weighted Voronoi diagram, was reported very recently despite that the problem may seem a straightforward extension of point generators. This talk will present the Voronoi diagrams of circular disks in the plane and spherical balls in the three-dimensional space. Theoretical issues, computational issues, and applications will be covered. In this talk, we will also introduce the concept of Molecular Geometry (MG) for a geometry-priority understanding on molecular systems of both organic and inorganic nature and will present MG Operating System (MGOS) which consists of callable functions based on the Voronoi diagram of spherical atoms that implements the MG theory. MG, accompanied by MGOS, will allow researchers to focus more on their primary research issues by freeing them from the time-consuming and error-prone tasks of highly sophisticated geometry algorithms for molecular structure studies. The impact of math libraries of general purpose high-level programming languages to science and engineering is an appropriate metaphor of that of MGOS. In this talk, diverse applications of MG/MGOS will also be presented. If MG and MGOS are properly accompanied by artificial intelligence techniques such as neural networks, they might contribute to practical, relatively poorly-defined real world problems in a significant way.

Research area(s): Theory and applications of Voronoi diagrams, Molecular geometry

Attempts towards the application of the self-organization in the reaction-diffusion systems

Daishin Ueyama
(Professor, Musashino University, Japan)

Abstract

I will introduce some of my attempts for the application of the self-organization arising on some reaction-diffusion systems. One is a mesh-generation method, which is based on the pattern formation on a reaction-diffusion system, so called the Gray-Scott model. The mesh produced by our method is qualitatively fine and has potential to extend problems in the higher dimension.

Research area(s): Theory and applications of Voronoi diagrams, Molecular geometry

“Foldable Products Based on Continuous Flattening Problems in Discrete Geometry”

Chie Nara
(Visiting Professor, Meiji University, Japan)

Abstract
Can we flatten empty containers of juice without cutting or stretching? The answer depends on conditions such as shapes and materials. The foldability is advantage, both carrying and storage, because of compactness. In this talk, by applying recent results on continuous flattening problems of polyhedral shapes in Discrete Geometry, and combining them with the Origami engineering, we introduce some examples of foldable products such as helmets and boxes. Basic ideas will also be introduced.

Research area(s): Kelvin expection, Tiling Polyhedron, Continuous Folding, Development