九州大学 IMI 共同利用・研究集会（Ⅱ）

# Fiber Topology Meets Applications

日時：　2021年1月6日（水）14:30 ～ 2021年1月8日（金）16:45
場所：　九州大学 伊都キャンパス ウエスト1号館 D棟4階
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## 1月6日（水）

14:30-15:15
Title : Fiber Topology Meets Applications: Where We are Heading
Speaker : Daisuke Sakurai (Kyushu University)

15:15-16:00
Title : Why Topology is Necessary at Exascale - And Why it's Not Easy
Speaker : Hamish Carr (University of Leeds)

16:00-16:45
Title : Modeling semiconductor epitaxy for next generation power device application
Speaker : Yoshihiro Kangawa (Kyushu University)

## 1月7日（木）

14:30-15:15
Title : Data Parallel Hypersweeps for in Situ Topological Analysis
Speakers : Petar Hristov (University of Leeds), Gunther Weber (Lawrence Berkeley National Laboratory and University of California, Davis), Hamish Carr (University of Leeds), Oliver Rübel (Lawrence Berkeley National Laboratory) and James Ahrens (Los Alamos National Laboratory)

15:15-16:00
Title : Design of Multimodal Test Problems in Multiobjective Optimization Using Fiber Topology
Speakers : Reiya Hagiwara (Kyushu University), Takahiro Yamamoto (Tokyo Gakugei University), Naoki Hamada (KLab Inc.), Daisuke Sakurai (Kyushu

University)

16:00-16:45
Title : Eco-efficient Flight Trajectory Exploration by Using the Chemistry-climate Model EMAC
Speakers : Hiroshi Yamashita and Bastian Kern (German Aerospace Center)

**<u>1月8日（金）</u>**

14:30-15:15
Title : Elimination of B2 singularities
Speaker : Takahiro Yamamoto (Tokyo Gakugei University)

15:15-16:00
Simplifying Indefinite Fibrations on 4-manifolds
Speaker : Osamu Saeki (Kyushu University)

16:00-16:30
Title : An Efficient Triangulation for Extruded Spatiotemporal Prism Meshes
Speakers : Akito Fujii, Kenji Ono and Daisuke Sakurai (Kyushu University)

16:30-16:45
Concluding Remarks
Daisuke Sakurai (Kyushu University)

## Abstracts

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### Fiber Topology Meets Applications: Where We are Heading

Daisuke Sakurai (Kyushu University)

In differential topology, the study of the topology of fibers, known as fiber topology, extends the Morse theory, of functions, to that of maps. This establishes a thorough exploration of topological transitions of inverse images. It has been proven powerful for understanding today’s data whose size and complexity are overwhelming. To aid
the interaction among mathematics, computation, and applications, we have launched this research gathering "Fiber Topology Meets Applications". This opening talk presents a general introduction to fiber topology, from the speaker's standpoint of computer science, and presents recent collaboration around him. Although each participant works on his own mission in his area, we have found a few fruitful directions that have mutual benefits to our rather diverse variety of disciplines. Key topics include topological analysis in high-performance computing and specialized treatments of discrete geometry in theoretical backgrounds of computation.

### Why Topology is Necessary at Exascale - And Why It's Not Easy

Hamish Carr (University of Leeds)

As computation scales to exabyte levels, humans are increasingly unable
to process the data directly. In a realistic assessment, a human might meaningfully perceive 10 GB of data in a lifetime, which requires billion-fold data reduction without information loss. As a result, techniques like computational topology, with mathematically well-founded approaches, become increasingly necessary to analyse and display (i.e. visualise) extreme data sets. However, much of the mathematics on which these methods are based is either linearly defined or couched in serial metaphors. As a result, one of the major challenges to exascale comprehension is now the ability to scale computational topology to massive hybrid systems using both shared-memory and distributed parallelism. This talk will therefore give an overview of the basic ideas behind computational topology at scale, and illustrate recent approaches to scalability.

### Modeling Semiconductor Epitaxy For Next Generation Power Device Application

Yoshihiro Kangawa (Kyushu University)

Gallium nitride semiconductor (GaN) is attractive material for next generation power device. A vertical GaN power device with a blocking voltage beyond 1200V is necessary for high-power modules in hybrid vehicles and electric vehicles. To develop such devices, it is indispensable to reduce carrier concentration in drift layer less than 1E+16 cm^−3. That is, it is indispensable to control unintentional doping during thin film growth. In the present work, we model elementary growth processes in GaN MOVPE (Metalorganic Vapor Phase Epitaxy) such as (1) vapor phase reaction, (2) surface reaction and (3) solid-phase diffusion during growth. In this presentation, we discuss how to control unintentional doping in GaN MOVPE from the theoretical viewpoint.

**Data Parallel Hypersweeps for In Situ Topological Analysis**

Petar Hristov (University of Leeds), Gunther Weber (Lawrence Berkeley National Laboratory and University of California, Davis), Hamish Carr (University of Leeds), Oliver Rübel (Lawrence Berkeley National Laboratory) and James Ahrens (Los Alamos National Laboratory)

The contour tree is a tool for understanding the topological structure of a scalar field. Recent work has built efficient contour tree algorithms for shared memory parallel computation, driven by the need to analyze large data sets in situ while the simulation is run- ning. Unfortunately, methods for using the contour tree for practical data analysis are still primarily serial, including single isocontour extraction, branch decomposition and simplification. We report data parallel methods for these tasks using a data structure called the hyperstructure and a novel general purpose approach called a hyper-sweep. We implement and integrate these methods with a Cinema database that stores features as depth images and with a web server that reconstructs the features for direct visualization.

**Design of Multimodal Test Problems in Multiobjective Optimization Using Fiber Topology**

Speakers: Reiya Hagiwara (Kyushu University), Takahiro Yamamoto (Tokyo Gakugei University), Naoki Hamada (KLab Inc.), Daisuke Sakurai (Kyushu University)

In industry, product designers often face a multiobjective optimization problem that requires to optimize multiple conflicting objective functions, such as cost and performance, simultaneously. In academia, researchers develop methods for solving multiobjective optimization problems based on performance comparison on artificial test problems. While multiobjective optimization problems that appear in real-world applications are often "multimodal", the definition of multimodality in multi-objective optimization was not well-established, and multimodal test problems supported by theory were not well developed. In this talk, we present a method for designing test problems that enable us to control their multimodality using fiber topology.

**Eco-efficient Flight Trajectory Exploration by Using the Chemistry-climate Model EMAC**

Hiroshi Yamashita and Bastian Kern (German Aerospace Center)

The climate impact of aviation emissions is a topic studied intensively due to its importance for a sustainable society. Climate-optimized routing of aircraft aims at minimizing climate impact. However, in reality, current routing models in the airline industry tends to optimize the financial cost of operation with little consideration on the environmental sustainability. To support governments and airlines in finding a practical solution to this trade-off between the financial and environmental costs, a product for the calculation of multi-objective flight trajectory optimizations is developed at our team. In this study, the flight trajectory optimization is carried out of flights from New York (JFK) to Paris (CDG) over the North Atlantic by using the chemistry-climate model EMAC with the air traffic submodel AirTraf. The compromise solutions in terms of the Pareto front or, more precisely, the nondominated front are analyzed. The talk also introduces the EMAC model in its first part.

**Elimination of B_2 Singularities**

Takahiro Yamamoto (Tokyo Gakugei University)

A smooth stable map of a compact manifold with boundary into a surface without boundary admits singularities which consists of folds, cusps, boundary folds, boundary cusps and B2 singularities. In this talk, we give a set of local moves for a smooth stable map of a compact manifold with boundary into a surface without boundary and study the following question. Given a compact surface with boundary M, and a smooth stable map f of M into the plane R^2, can f be deformed to a smooth stable map g so that g has no B2 singularities.

**Simplifying Indefinite Fibrations on 4-manifolds**

Osamu Saeki (Kyushu University)

A broken Lefschetz fibration (BLF, for short) is a smooth map of a closed oriented 4-manifold onto a closed surface whose singularities consist of Lefschetz critical points together with indefinite folds. Such a class of maps was first introduced by Auroux-Donaldson-Katzarkov (2005) in relation to near-symplectic structures. In this talk, we give a set of explicit moves for BLFs, and give an elementary and constructive proof to the fact that any map into the 2-sphere is homotopic to a BLF with embedded singular set image. We also show how to realize any given null-homologous 1-dimensional submanifold with prescribed local models for its components as the round locus of a BLF. These algorithms allow us to give a purely topological and constructive proof of a theorem of Auroux-Donaldson-Katzarkov on the existence of broken Lefschetz pencils with embedded round image on near-symplectic 4-manifolds. We moreover establish a correspondence between BLFs and Gay-Kirby trisections of 4-manifolds, and show the existence of simplified trisections on all 4-manifolds.
This is a joint work with R. Inanc Baykur (University of Massachusetts).

**An Efficient Triangulation for Extruded Spatiotemporal Prism Meshes**
Akito Fujii, Kenji Ono and Daisuke Sakurai (Kyushu University)

It is common to run simulations on a spatial mesh with an associated (spatial) triangulation. We consider the problem of re-triangulating space-time mesh that conforms to the pre-defined spatial triangulation. The problem originates in computer graphics where shell maps were concerned about 3D geometry. Today the general dimensionality, and especially 4D, has become relevant for online (aka in-situ) analysis, in which a diagnostic program component examines the simulated physical fields. As the analysis is especially important for visualizing big data from scientific computation, providing a spatiotemporal triangulation equipped with the very fine temporal resolution thanks to in-situ opens the door to a new variety of diagnoses. This article proposes an instant combinatorial triangulation, which is ¥emph{implicit} in the sense that the triangles can be determined on-the-fly and locally for an arbitrary sub-complex of the space-time. In other words, the algorithm does not have to iterate over all the vertices to determine the triangles and is thus efficient in a range of scenarios.
Our algorithm is also scalable in distributed memory machines, on which simulators would run. We assume a static spatial triangulation, which is rather simplistic yet found in today's simulations, including atmospheric simulations run in academia and even at meteorological agencies. For such a static triangulation we extrude them along the time axis, which gives us a prism mesh, and further re-triangulate them to get the spatiotemporal triangulation.
Being combinatorial, implementations of the algorithm do not require arbitrary precision arithmetic. Our algorithm is easy to implement, inserts no additional

vertex, is memory efficient, works for arbitrary dimension and is parameter free.