The HeKKSaGOn Mathematics Group

Mathematics at the Interface of Science and Technology

Goals and Projects for the Funding Period 2024 - 2027

MANIFESTO

Overall Objective

Mathematics has a long history of providing the common language and the appropriate intellectual frame for other disciplines. In this classical scheme, mathematical new breakthroughs do not a priori affect other sectors of society, except in a longer perspective. However, in the last decades an additional and new paradigm has also emerged. Indeed, modern human societies do nowadays encounter many urgent technology-based problems which have become more and more complicated and harder to handle. Complexity phenomena arising in, e.g., artificial intelligence, big data, robotics, genetics and structural biology, are now often beyond the efficiency zone of the existing tools. In this new context, Mathematics, providing a unifying view, can take direct action. The objective of our working group – which, as we are proud of to note, is presently consisting of more than two dozen members from all six HeKKSaGOn Alliance universities – is to promote cooperative research activities among the six universities in corresponding custom-made applications of mathematics as well as in advancing the frontiers of pure mathematics and its application to theoretical quantum physics. We will do this by balancing seeds in mathematics and needs outside mathematics. This is based on the insight that to attack new real world problems we need new mathematical concepts and methods, and that new applications of mathematics will in turn also stimulate the development of new mathematical theories.

In particular, our planned joint research, training and other activities – individually detailed in separate attachments to this manifesto, whereas here their common grounds and motivations are explained – pertain to and will enhance corresponding progress in both the new HeKKSaGOn priority areas.

- Data Science, Digitalization and Artificial Intelligence, as well as
- Life Science, Medicine and Changing Environments.

1. Individual objectives and expected outcomes

1. Geometry and Statistics

   Doing geometry on high-dimensional differential and more general spaces constitutes one of the most research-intensive areas of mathematics in recent decades. It has a long tradition that traces its development back well over a century. Its current prominence stems from its position at the crossroads of many active fields such as: algebraic, complex, Riemannian and symplectic geometry, topology, metric geometry, analysis, geometric control and modeling, partial differential equations, Lie theory, and, most recently, probability and statistics.

   Regarding specifically the importance of the development of new geometrical, statisticsical and stochastical methods for the HekkSAGOn priority area ' *Data Science, Digitalization and Artificial Intelligence*, we note, as has also been impressively demonstrated by last year's Göttingen HeKKSaGOn AI Symposium, that data-driven sciences are widely regarded as the next paradigm that can fundamentally change sciences and pave the way for a new industrial revolution. In passing now from (merely) topological to *geometric* data analysis we see now that differential, computational and discrete geometry have achieved first and great successes in data characterization and modelling. In particular, geometric deep learning has significantly advanced the capability of learning models for data with complicated topological and geometric structures. The combination of geometric methods with learning models has thus great potential to fundamentally change the data sciences, and the involved disciplines, methods, and techniques nowadays include, but are not confined to, discrete exterior calculus and Laplace Operators, discrete optimal transport, and geometric flow, discrete Ricci (like Olivier and Forman type) curvatures, conformal geometry, combinatorial Hodge theory, dimension reduction via manifold learning, Isomap, Laplacian eigenmaps, diffusion maps, hyperbolic geometry, Poincaré embeddings, etc., geometric signal processing and deep learning, graph, simplex and hypergraph neural networks, index theory, information geometry and (Gromov -) Hausdorff distance, and as to the interactions with theoretical physcis, see also our section on topology and topological quantum field theory below.

   Especially in statistical applications, central limit theorems are a main tool for studying inference phenomena, and rates and distributions of central limit theorems may be heavily influenced by topological and geometric invariants of the underlying spaces.

   Indeed, recent and current work shows that non-Gaussian limiting theorems may occur and have impact on many situations and that such effects may even increase with dimension. In consequence, if one uses the wrong limiting distribution and rate, confidence statements are wrong. The recent financial crisis may actually serve here as a quite drastic example where, among others, inadequate Gaussian models led to too light-tailed distributions, falsely neglecting extremal events.

Another challenging topic, which is closely related to the above, is equally not only of high theoretical interest in itself but also shows great potential for applications, consists of the general problem of reconstructing and approximating singular spaces like Alexandrov spaces, point data, varieties, metric measurement configurations etc. by more regular or even smooth ones. Here general recognition tools as well approximation theorems in terms of suitable convergence theories for, e.g., Gromov-Hausdorff, Gromov-Wasserstein and intrinsic current convergence will have to be developed in the context of metric measure spaces.

As one main and general goal of the future work of the HeKKSsaGon mathematics working group, we thus want to develop and explore limiting and approximation theorems on very general spaces carrying a geometric structure. This goal splits into two subgoals: First to model and validate a new theory for non-Euclidean central limit theorems on manifolds and more general spaces. The second, and equally important subgoal, will be to attack the general approximation and reconstruction problem. To achieve these aims along with its more specific as well as different aspects and ramifications, we will have to rely on as well as combine the expertise of all members involved so far. This has already been very successful in problems arising from fingerprint analysis, phylogenetics and structural biology. In addition, here we also expect new interdisciplinary interactions and collaborations with other working groups, especially in robotics - see below.

2. Mathematical Challenges in Robotics

   There are manifold current research topics in robotics where mathematical tools, especially ones from geometry, can be successfully applied., e.g., in issues in machine learning for robotics, safe human-robot collaboration, motion planning and control for robots as well as medical robotics. Indeed, at KIT there have already been many joint interactions between researchers in medical robotics and geometry, among them Ledermann, Pauer, Tuschmann, Woern, and others, leading to several joint publications in the field of shape sensing and sensorics. It goes without saying that these undertakings will have impacts to the HeKKSaGOn research priority area *Life Science, Medicine and Changing Environments*, but we would also like to note that, e.g., motion government and computer vision challenges from and inside humanoid robotics, where, headed by Tamim Asfour from

KIT, HeKKSaGOn has an active working group itself, should also stir new interactions between ours and his group and ultimately contribute to the the HeKKSaGOn research priority area *Life Science, Medicine and Changing Environments*.

3. Mathematical Challenges in Phylogenetics and Structural Biology

   Determining structure and biological function of structural elements such as proteins and RNA from their genetic code is one fundamental cornerstone in the progress of medicine. Some pathogens, e.g. cancer cells and many viruses are also subject to short term biological evolution. Uncovering their past phylogenies as well as successfully predicting future evolutive pathways is another cornerstone for medical progress. Both cornerstones are mathematically linked by statistical shape analysis, employing novel non-Euclidean methods for data science, be it for 3D structure (proteins, RNA) or for (phylogenetic) trees, or more general graphs (e.g. to model hybridisation). In Göttingen there is a lively interaction between non-Euclidean statistics and structural biology funded by several DFG CRCs, among others involving Eltzner, Huckemann and Wiechers from the side of mathematics, and the research and further activities to be conducted here will, as far as the application side is concerned, be targeted to yield new contributions to the HeKKSaGOn research priority area *Life Science, Medicine and Changing Environments*.

4. Analysis

   The Navier-Stokes equations describe the motion of fluids. The behavior and properties of solutions to the Navier-Stokes equations are useful in many practical applications, for instance, in weather forecast, aircraft manufacturing, atmospheric pollution, and so on. However, even the fundamental mathematical question on existence and uniqueness of global solutions to the Navier-Stokes equations for arbitrary initial data is still open. Indeed, he Clay Mathematics Institute proposed the problem entitled "Navier-Stokes existence and smoothness" as one of the seven Millennium Prize problems in Mathematics. We will contribute to this goal, concentrating on proving smoothness of the solution of the Navier-Stokes equations by using the method of the maximal regularity theorem, with the aim to ultimately make these results also applicable for applications in meteorology, thus relating to the HeKKSaGOn research priority area *Life Science, Medicine and Changing Environments*.

5. Topological Quantum Field Theory and Topology

   The central goal of fundamental theoretical physics is the description of the consituents of the world and how they interact to form the world as we observe it. This relates to elementary particles, fundamental forces and their dynamics. The powerful and successful mathematical tool to achieve this are quantum field theories. Indeed, there is not just one such, but many, and these are expected to be necessary to attack the basic challenges of fundamental physics like: the explanation of dark matter and dark energy, the taming of anomalies, and the quantization of gravity and general relativity. Special contenders of relevant theories are string theories and conformal field theories. The different quantum field theories describe different possibilities for the world, with different types of symmetries and different dimensions for their space-time. Some are toy-models whose full mathematical understanding will provide precious information in the understanding of realistic models, others are true contenders for a full mathematical description of elementary particle physics.

To get a complete picture we need an understanding of the collection of all quantum field theories (of given characteristics). These form a topological spectrum which is conjecturally well understood (Stolz-Teichner, Freed-Hopkins). The research direction now aims to explore these structures and draw conclusions for our understanding of topology and fundamental quantum physics.

Physics predicts important dualities (two different theories, which are equivalent by describing the same physical system), among them mirror symmetry and T-duality. It is an open mathematical challenge to prove that these symmetries actually exist in mathematical rigorous form, and to draw further consequences.

6. Topological phases of matter and operator algebras

   In solid state theory, the last decades have seen the theoretical (and experimental) creation of completely new phases of matter which are topologically protected (i.e. robust under perturbations) and which display exciting phsycial properties (e.g. being an insulator in the bulk while conduction at the boundary). These states of matter are also called "topological" because their description via effective Hamiltonians relies of topological invariants like Chern classes. It has been observed that the most efficient way to classify the different topological phases is done via K-theory, in more refined ways the K-theory of C^*-algebras. Otiginally, these descriptions used strong chrystal symmetry properties, but fundamental work of Kubota in Kyoto and Ewert-Meyer in Göttingen has highlighted the role of large scale geometry and the boundedness of interaction between the atoms in a solid, which explains then also the topological robustness of the phenomena. This observation has spurred intense follow-up research all over the world.

Many challenges remain, like the geometries which support such topological phases, the role of torsion phenomena in K-theory and the associated topological invariants and the construction of new invariants, in particular of index theoretic kind (these should include the subtle torsion invariants and how they can be efficiently calculated).

2. Concrete perspectives and plans for future collaborations

1. Geometry and Statistics

   In the spirit of our objectives in geometry and statistics, members of the Geometry Groups at KIT and the Statistics Groups at Göttingen (Eltzner, Galaz-Garcia, Huckemann, Tuschmann) have recently obtained in joint work a Central Limit Theorem for closed Riemannian manifolds, clarifying along the way the geometric meaning of some of the hypotheses in Bhattacharya and Lin's Omnibus Central Limit Theorem for Fréchet means. We obtain our CLT assuming certain stability hypothesis for the cut locus, which always holds when the manifold is compact but may not be satisfied in the non-compact case. Moreover, members from Göttingen around Prof. Huckemann and Prof. Oshika (formerly at Osaka) have successfully collaborated and published on issues centering around fingerprint analysis.

   These results should be extendable to a way more abstract setting, namely, to Alexandrov and metric measure spaces, where especially geometers like Prof. Yamaguchi and Prof. Kato, both at Kyoto, and Prof. Shioya and collaborators at Tohoku, can profoundly contribute with their strong expertise in these matters.

2. Mathematical Challenges in Robotics

   Beyond the existing joint projects between some of the KIT geometry and robotics groups, we strive to enlarge collaborations, especially with members from other Hekksagon universities and attack new interdisciplinary problems. A very promising topic here is now the joint study of medical robots, gaining interest in the field of healthcare due to their manifold advantages, such as enabling minimally-invasive surgical procedures with high precision, reduced tremor, and direct feedback from various sensors to the surgeon. However, we also seek for collaborations in other fields like, e.g., humanoid robotics, represented by the group of Asfour at KIT, that will inspire new mathematics.

   This directly links to research in Göttingen. Closely mimicking the biomechanical structure of human joints is challenging, in particular for the knee joint. To this end, among others, the group around Huckemann in Göttingen has developed methods to reliably measure with statistical guarantees unobserved bone motion from skin markers. In a broader context, close relations have also been illustrated at the recent (2023) HeKKSaGOn AI Symposium in Göttingen by the group of Wörgötter in directions of computational neuroscience of the visual system and its functional connectivity.

However, there is even more to say here. We actually think that this topic is an especially suitable and important one to explore inside the realms of HeKKSaGOn. Indeed, nowadays both Germany and Japan are confronted with an aging and already overaged society. But our countries do also play leading roles in both mathematics and robotics, and mathematically enhanced progress in robotics can and will thus also be directly beneficial to our nations.

3. Challenges in Mathematical Biology

   Many areas in mathematical biology suffer from low sample sizes that do not allow for machine learning methods "from the shelf". We amend for this by including as much biology, as possible, in our models. Usually, this leads to challenging model spaces, such as the recently, among others in Göttingen developed *wald space*: A stratified space featuring a, to date only poorly, understood geometric structure with unbound positive and negative curvatures. In collaboration with geometry, statistics and optimization we seek to discover the geometric structure, develop suitable limit theorems and inferential methods. Putting these into action, requires development of novel optimization methods in nonconvex environments in collaboration with the group of Luke (Göttingen). In collaboration with groups in phylogeny (Shimodaira, Kyoto and Terada, Osaka) and the German Primate Center (Göttingen) we plan to link non-Euclidean behavior of limit theorems to fundamental biological questions, e.g inferring on hybridisation events.

   Similar mathematical methods have been already successfully employed in a joint collobaration in Göttingen between non-Euclidean statistics and the Max Planck Institute for Multidisciplinary Sciences in Electron Paramagnetic Resonance Spectroscopy for structural biology. Faithfully representing biochemical structure leads to spaces that are similarly stratified in a nonstandard manner. Again, the joint challenge for geometry, statistics and optimization lies in uncovering the geometric structure, developing specifically tailored statistical methods and providing numerics to actually perform computations. This collaboration has already led to new biological insight, jointly with biophysical chemistry uncovering new conformational structure. Another application of recently developed non-Euclidean smart statistical learning from low sample sizes has been the "correction" of a clashing suite in the SARS-CoV-2's frameshift stimulation element.

Starting in the pandemics, now successfully continuing, there are frequent joint online seminar meetings involving students at various levels (graduate, PhD, postdocs) and researchers.

4. Challenges in Analysis

   The maximal regularity theorem has been developed and developing for the last three decades, and Karlsruhe Institute of Technology (KIT) has been one of the centers for research on the maximal regularity theorem. Especially, Prof. Lutz Weis (KIT, Prof. Emeritus) and Prof. Kunstmann (KIT) are well known at the world wide level. In fact, they made essential contributions to the maximal regularity theorem and their results have been applied to the method of solvability of nonlinear partial differential equations describing various phenomena in physics, engineering, other sciences and technologies. Prof. Kozono (Tohoku) and Prof. Shimizu (Kyoto) who are renowned experts concerning the Navier-Stokes equations have a research plan jointly with Kunstmann. They will study analyticity of solutions to the Navier-Stokes equations and that of the quasi-geostrophic flow through the parameter trick method which is based on the maximal regularity theorem.

5. Topological Quantum Field Theory and Topology

   Mathematician Yamashita (Kyoto) obtained recent breakthrough results in the absence of global anomalies within the space of quantum field theories topologically classified by topological modular forms. This and other achievements resulted in her winning the 2024 Dannie-Heinemann Prize of the Göttingen Academy of Sciences and Humanities in Lower Saxony. Physicist S. Yamaguchi (Osaka) and Yamashita have joint publications on analytic aspects of QFTs using index theory of the Dirac operator, which is also key competence of Meyer (Göttingen) and Schick (Göttingen). Physicist Yonekura (Osaka) and Yamashita used differential cohomology theories to classify non-topological invertible quantum field theories as a spectrum. This is complemented by expertise of Schick (Göttingen) who axiomized with Bunke differential cohomology theories.

   The project will finalize the topological classification of topological quantum field theories initiated by Yamashita (Kyoto) with Yonekura (Osaka) and independly by Kubota and Ogata (both Kyoto), using also higher order structures, for which Zhu (Göttingen) and Hao (Göttingen) are experts. Applications to mirror symmetry and the study of conformal field theories will be achieved jointly with Walcher (Heidelberg) and Yamaguchi (Kyoto).

6. Topological phases of matter and operator algebras

The fundamental insight that large scale geometry and the K-theory of the associated operator algebras efficiently describes the topologically protected phases of matter has been made independently by Kubota (Kyoto) and Meyer (Göttingen, with M.Sc. student Ewert). Further expertise in large scale geometry and the use of K-theory and operator algebras is provided by Schick (Göttingen), who has joint publications with Kubota on the use of K-theory and operator algebras in geometry and topology. From the physics side, Ohyama (Kyoto) has expertise in the construction and description of one-dimensional topological systems with exciting properties in 1+1 dimensional systems. Again from a theoretical physics perspective, Shiozaki (Kyoto) uses sophisticated algebraic topology tools like the Atiyah-Hirzubruch spectral sequence to work towards a complete classification of topological insulators, which should be complemented by the expertise of professional algebraic topoologists like Banagl (Heidelberg) and Schick (Göttingen).

The questions to be attacked include the extension of the classification combining large scale geometry and higher algebraic topology.

Planned Concrete Activities for the Funding Period 2024 - 2027

For the further concrete individual activities that we are planning to achieve the goals and milestones presented above in the next HeKKSaGON funding period, see the detailed individual proposals accompanying this document, where also further information in regard to the general selection criteria is provided.

Four Workshops Plan for 2024 – 2027

1. Conference "Non-Euclidean Spaces in Life Sciences: Geometry, Optimization and Statistics" (3 days in November/December 2024 in Göttingen, expecting approx. 20 participants, 10 from overseas), costs approx. 22,000 Euros, 3,000 covered by the "Internationalisierungsfond" of the Mathematics Department, Göttingen.

   Description The proposed conference explores new and overarching methodology at the interface between numerics and statistics on the one side, and geometry, topology and stochastics on the other side, inspired by demands from the life sciences.

   Phrasing typical demands in robotics, phylogenetics, micromolecular structure and machine learning, say, in mathematical language leads to new and challenging problems for statistics, numerics and stochastics on non-Euclidean spaces, requiring development of new and deep insight into subtle topological and geometric structures.

The conference will highlight recent advances in e.g. singular spaces, stochastic differential equations on stratified spaces, non-Euclidean limit theorems thereon and related numerical optimization, linking to "Mathematics of Experiment" (SFB 1456), engineering and machine learning, aiming at fostering communication between experts and young researchers, as well as identifying new directions of further research in these fields.

This conference continues an ongoing fruitful collaboration within the HeKKSaGOn Alliance of scientists from diverse and typically isolated fields, advancing the frontiers of pure and applied mathematics by balancing seeds in mathematics and needs outside mathematics.

2. 2025 Satellite (to Presidents' Meeting) Workshop in Osaka (organized by Prof. Goto) in November.

3. 2026 Workshop KIT (organized by Tuschmann, Schick and Huckemann)

4. 2027 Workshop at RIMS, Kyoto, organized by Prof. Shimizu, including a tandem workshop in Göttinen (organized by Prof Schick, for some who will not travel), potentially related to Presidents' Meeting.

All Workshops will be preceded by tutorials for young researchers, they will be complemented by funded longer stays of individual collaborators from the partner universities.

Investment for collaboration

The need and desire to cooperate and interact between East Asia and Europe is important for the advancement of science and the progress of our projects. However, it has to be balanced by the goal to protect the environment and protect the climate.

In light of this, we plan to organize some of our meetings as *tandem meetings*. This means that the event happens at the same time in two locations, one in Germany and one in Japan. Participants from Europe will meet at the German side, participants from Asia at the Japanese node. This will already create a critical mass for the indispensible direct interaction and exchange (also the informal one during coffee breaks and joint meals). This will be complemented by several hours per day of joint hybrid activity which fosters the exchange between the two nodes (due to the time difference, this will apply to only part of the activities per day).

It is proven that such models work, e.g. by tandem workshops between the renowned Mathematische Forschungsinstitut Oberwolfach and the Research Institute for Mathematical Sciences (RIMS), precisely located at Kyoto university. However, it has also proven to be fundamental that top notch videoconference equipment is used, in particular with high end sound systems.

Such equipment is not yet available in the required quality in the mathematics faculty in Göttingen. As part of the initiative, we plan to invest in such equipment, supported by the HeKKSaGON funds.

3. Present Members of the HeKKSaGOn Mathematics Group

Prof. Dr. Wilderich Tuschmann, KIT (Chair)
Prof. Dr. Takashi Shioya, Tohoku University (Co-Chair)

Prof. Dr. Peter Albers, Heidelberg University
Prof. Dr. Anna Marciniak-Czochra, Heidelberg University
Prof. Dr. Beatrice Pozzetti, Heidelberg University
Dr. Johannes Resin, Heidelberg University
Prof. Dr. Petra Schwer, Heidelberg University

Prof. Dr. Tilmann Gneiting, KIT
PD Dr. Peer Kunstmann, KIT
Dr. Philippe Kupper, KIT
Dr. Kaori Nagatou, KIT
Dr. Artem Nepechiy, KIT
Prof. Dr. Roman Sauer, KIT

Prof. Dr. Tsuyoshi Kato, Kyoto University
Prof. Dr. Senjo Shimizu, Kyoto University
Prof. Dr. Satoshi Tsujimoto, Kyoto University

Prof. Dr. Hideo Kozono, Tohoku University
Prof. Dr. Hiroshi Suito, Tohoku University
Prof. Dr. Jun Masamune, Tohoku University

PD Dr. Benjamin Eltzner, University of Göttingen
Dr. Carsten Gottschlich, University of Göttingen
Prof. Dr. Stephan Huckemann, University of Göttingen
Prof. Dr. Russell Luke, University of Göttingen
Prof. Dr. Ralf Meyer, University of Göttingen
Dr. Susovan Pal, University of Göttingen
Prof. Dr. Thomas Schick, University of Göttingen
Dr. Henrik Wiechers, University of Göttingen
Prof. Dr. Chenchang Zhu, University of Göttingen

Prof. Dr. Ryushi Goto, Osaka University
Prof. Dr. Hisashi Kasuya, Osaka University
Dr. Yoshihisa Miyanishi, Osaka University
Prof. Dr. Takashi Nakazawa, Osaka University
Prof. Dr. Katsutoshi Yamanoi, Osaka University

4. Previous and current scientific activities and achievements

(A) Held Conferences, Symposia, Workshops and Seasonal Schools

1. HeKKSaGOn Workshop 'Metrics and Measures', September 28-29, 2023, Tohoku University.
2. HeKKSaGOn Workshop 'Analysis, Geometry and Stochastics on Metric Spaces', September 25-27, 2023, RIMS, Kyoto.
3. HeKKSaGOn AI Symposium, September 19-21, 2023, Göttingen, jointly with the working groups Data Science and Robotics, preceeding the 9th German-Japanese University Presidents' Conference, September, 21-22, 2023, Göttingen.
4. 6th German-Japanese University Presidents' Conference, Working Group Meeting, April 12-13, 2018, Osaka.
5. HeKKSaGOn Mini-Workshop 'Geometry meets Stochastics: Smeariness and Pattern Recognition', December 12-13, 2017, KIT.
6. HeKKSaGOn Working Group Winter School in Osaka 2017, March 2-12, 2017, Osaka University.
7. HeKKSaGOn Mini-Workshop 'Perspectives and Challenges in Mathematical Sciences', October 1, 2016, KIT.
8. 5th Japanese-German University Presidents' Conference, Working Group Meeting, September 29-30, 2016, KIT.
9. HeKKSaGOn Mini-Workshop 'Frontiers in Mathematical Sciences', April 18, 2015, Tohoku University, Sendai.
10. 4th Presidential Conference HeKKSaGOn, Working Group Meeting, April 2015, Tohoku University, Sendai.
11. Summer School 'Inference of Pattern Formation: Applications in Natural and Materials Sciences', September 15-19, 2014, Göttingen.
12. Mini-Workshop on Approaches from Discrete Mathematics, PDEs and Stochastics to Pattern Recognition, September 14, 2013, Göttingen.
13. HeKKSaGOn Summer School on Crossing Borders: Unraveling Principles of Life with Quantitative Tools, September 17–26, 2012, Heidelberg.
14. Turing Symposium on Morphogenesis, Mathematical Approaches Sixty Years after Alan Turing, August 27–31, 2012, Sendai.
15. Workshop on Mathematical Models of Biological Phenomena and their Analysis, November 21-24, 2011, Sendai.

(B) Selection of joint scientific publications

1. A. Marciniak-Czochra, M. Nakayama, I. Takagi, "Pattern formation in a diffusion-ODE model with hysteresis", Differential Integral Equations 28 (2015), 655-694.
2. S. Härting, A. Marciniak-Czochra and I. Takagi, "Stable patterns with jump discontinuity in systems with Turing instability and hysteresis", Discrete Continuous Dynamical Systems Ser. A, 38 (2017), 757-800.
3. Imdahl, C., Gottschlich, C., Huckemann, S., Ohshika, K., "Möbius moduli for fingerprint orientation fields" J. Math. Imaging Vision 60 (2018), 651-660.
4. Takashi Shioya, Asuka Takatsu, "High-dimensional metric-measure limit of Stiefel and flag manifolds", Mathematische Zeitschrift 290(2018), 1-35.
5. Hiroki Nakajima, Takashi Shioya, "Isoperimetric rigidity and distributions of 1-Lipschitz functions", Advances in Mathematics 349(2019), 1198–1233.
6. Terada, Y., Ogasawara, I., and Nakata, K., "Classification from only positive and unlabeled functional data", Annals of Applied Statistics, 14 (4), 1724–1742 (2020)
7. Benjamin Eltzner, Fernando Galaz-Garcia, Stephan F. Huckemann, Wilderich Tuschmann, "Stability of the Cut Locus and a Central Limit Theorem for Fréchet Means of Riemannian Manifolds", Proceedings of the American Mathematical Society 149, 3947-3963 (2021)
8. Hideo Kozono, Peer Kristian Kunstmann, Senjo Shimizu, "Analyticity in space-time of solutions to the Navier-Stokes equations via parameter trick based on maximal regularity", Annali Scuola Normale Superiore 34pp (2023).
9. Terada, Y. and Shimodaira, H., "Selective inference after feature selection via multiscale bootstrap", Annals of the Institute of Statistical Mathematics, 75, 99–125 (2023)

For further information and details please consult our

HeKKSaGON Mathematics Group Website: `http://www.hekksagon.net/92.php`