Faculty Introduction 2024

Graduate School of Mathematics, Nagoya University

(April 1, 2024)

CONTENTS

ARANO, Yuki — Associate Professor

Office: Rm 304 in Math. Bldg.
Phone: +81 (0) 52−789−4877 (ext. 4877)
Email: y.arano@math.nagoya-u.ac.jp
Web-site: https://www.math.nagoya-u.ac.jp/~y.arano/index.html

Membership of Academic Societies:
The Mathematical Society of Japan

Research Interest:

- Operator algebra
- Quantum group
- Tensor category

Research Summary:

An operator algebra is a certain subalgebra of the algebra of all bounded operators on a Hilbert space. Such algebra can be seen as a "noncommutative version" of the algebra of all continuous functions on a topological space. In the operator algebraic quantum group theory, we study the group structure on such "noncommutative" space. Not only such quantum group gives important examples of operator algebras, but also this appears as an analogue of the Galois group in the subfactor theory.

My interest is the repretation theoretic/topological aspects of quantum groups. Along this line, I also worked on the actions of quantum groups on operator algebras and more general tensor categories etc.

Major Publications:

[1] Y. Arano, Unitary spherical representations of Drinfeld doubles. *J. Reine Angew. Math.* **742** (2018), 157–186

[2] Y. Arano, Comparison of unitary duals of Drinfeld doubles and complex semisimple Lie groups. *Comm. Math. Phys.* **351** (2017), no.3, 1137–1147.

[3] Y. Arano, Y. Isono. A. Marrakchi, Ergodic theory of affine isometric actions on Hilbert spaces, *Geom. Funct. Anal.* **31** (2021), no.5, 1013–1094.

Awards and Prizes:

- 2017, The Takebe Katahiro Prize for Encouragement of Young Researchers, "Studies of operator algebraic quantum groups"

Education and Appointments:

2017	Assitant professor, Kyoto University
2023	Associate professor, Nagoya University

Message to Prospective Students:

Standard textbooks on my field are, for example,

- Murphy, Gerard J. C*-algebras and operator theory. Academic Press, Inc., 1990
- Jantzen, Jens Carsten. Lectures on quantum groups. Graduate Studies in Mathematics, 6. American Mathematical Society,, 1996
- Neshveyev, Sergey ; Tuset, Lars. Compact quantum groups and their representation categories. Cours Spécialisés, 20. Société Mathématique de France, 2013.

but you may study anything related to operator algebras and quantum groups.

During the seminar, I would recommend you not to see any memos. This does not mean you need to memorize everything. You need to understand the contents as deep as, for example, the high school math. (I suppose you can talk about the definition and the basic properties of a derivative of a single variable without seeing anything.)

You are required to understand calculus, linear algebras, topology, basic group theory, measure theory, Fourier analysis and functional analysis before entering the graduate school. Undrstanding any further math such as representation theory, probability theory, algebraic topology and mathematical physics would be appreciated, but deep understanding of basic math is much more important.

Office: Rm 306 in Math. Bldg.
Phone: +81 (0) 52–789–5601 (ext. 5601)
Email: awata@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~awata/
Membership of Academic Societies:
The Mathematical Society of Japan

Research Interest:

- Quantum field theory
- Representation theory of infinite dimensional algebras
- Symmetric function

Research Summary:

H. Awata works in the areas of representation theory and quantum field theory, which involve the representation theory of infinite dimensional algebras such as Virasoro algebra, W algebra and affine Lie algebra and also involve the quantum field theories possessing one of these algebras as a symmetry such as super string theory, conformal field theory, two dimensional solvable model and topological field theory. Much of his work focuses on studying (q-deformed) Knizhnik-Zamolodchikov equation, Jack polynomial, Macdonald polynomial and Nekrasov's partition function. He is currently focusing on a study of the AGT conjecture, which reveals the relation between the conformal field theory and the Nekrasov's partition function.

Major Publications:

[1] with Akihiro Tsuchiya and Yasuhiko Yamada, "Integral formulas for the WZNW correlation functions," Nuclear Physics **B365** (1991), 680–696.
[2] with Satoru Odake and Jun'ichi Shiraishi, "Free Boson realization of $U_q(\widehat{sl_N})$," Communications in Mathematical Physics **162** (1994), 61–83
[3] with Masafumi Fukuma, Yutaka Matsuo and Satoru Odake, "Representation Theory of the $\mathcal{W}_{1+\infty}$ Algebra," Progress of Theoretical Physics, Supplement **118** (1995), 343–373
[4] with Harunobu Kubo, Satoru Odake and Jun'ichi Shiraishi, "Quantum W_N Algebras and Macdonald Polynomials," Communications in Mathematical Physics **179** (1996), 401–416
[5] with Miao Li, Djordje Minic and Tamiaki Yoneya, "On the Quantization of Nambu Brackets," Journal of High Energy Physics 0102 (2001) 013
[6] with Hiroaki Kanno, "Instanton counting, Macdonald function and the moduli space of D-branes," Journal of High Energy Physics 0505 (2005) 039.
[7] with Yasuhiko Yamada, "Five-dimensional AGT Conjecture and the Deformed Virasoro Algebra," Journal of High Energy Physics 1001 (2010) 125.
[8] with Boris Feigin and Jun'ichi Shiraishi, "Quantum Algebraic Approach to Refined Topological Vertex", Journal of High Energy Physics 1203 (2012) 041.

Education and Appointments:

1993 Soryushi-Syogakkai fellow at Yukawa Institute for Theoretical Physics, Kyoto University
1994 JSPS fellow at Research Institute for Mathematical Science, Kyoto University
1995 JSPS fellow at Yukawa Institute for Theoretical Physics, Kyoto University
1996 Visiting Scholar at Enrico Fermi and James Frank Institutes of Chicago University
1998 COE at Yukawa Institute for Theoretical Physics, Kyoto University
1999 Associate Professor at Graduate School of Mathematics, Nagoya University

Message to Prospective Students:

- The basic literature,

  J. Polchinski, "String Theory", Cambridge univ. press, 1998.

  V. Kac, "Infinite dimensional Lie algebras", Cambridge univ. press, 1990.

  I.G. Macdonald, "Symmetric functions and Hall polynomials", Second Edition, Oxford University Press, 1995.

Office: Rm 407 in Math. Bldg.

Phone: +81 (0)52−789−5603 (ext. 5603)

Email: futaba@math.nagoya-u.ac.jp

Membership of Academic Societies:
AMS (American Mathematical Society)
ICA (The Institute of Combinatorics and Its Applications)

Research Interest:

- Graph Theory

Research Summary:

Graphs have been studied through a number of aspects such as connectivity, colorings and labelings, decompositions and factorizations, traversability, etc. In my research, I study traditional concepts including those mentioned above as well as try coming up with new ways of looking at graphs that may shed some light on other concepts and problems in mathematics.

The connectivity of a connected graph is the smallest number of vertices that disconnect the graph when deleted. Menger's Theorem suggests that studying the connectivity of a graph is closely related to studying the number of internally-disjoint paths connecting each pair of vertices in the graph. In [2], a new parameter of graphs was introduced. For a nontrivial connected graph G and a nonempty non-singleton set $S \subseteq V(G)$, the number $\kappa(S)$ is the maximum number ℓ such that there is a collection $T_1, T_2, \ldots, T_\ell$ of ℓ pairwise edge-disjoint trees with $V(T_i) \cap V(T_j) = S$ for $1 \le i \ne j \le \ell$. The k-connectivity of G is then defined to be $\min\{\kappa(S)\}$, where the minimum is taken over all k-subsets S of $V(G)$. This generalizes the traditional concept of connectivity of graphs, where the standard connectivity is exactly the 2-connectivity. Roughly speaking, the k-connectivity of a graph can be seen as the number of "independent" ways for a set of k individuals in a network to communicate with each other.

Another popular area of research in graph theory is graph coloring. For example, the famous Four Color Theorem states that every planar graph has a proper 4-coloring. Colorings that deserve our attention include those that distinguish either every two vertices or every two adjacent vertices in a graph in some manner. Colorings possessing such properties are said to be vertex-distinguishing and neighbor-distinguishing, respectively. I have introduced and studied numerous new vertex-distinguishing colorings and neighbor-distinguishing colorings with my research partners. The sigma coloring in [1] is an example of the latter.

Major Publications:

[1] G. Chartrand, F. Okamoto, and P. Zhang, The sigma chromatic number of a graph, Graphs Combin., 26:6 (2010) 755–773.

[2] G. Chartrand, F. Okamoto, and P. Zhang, Rainbow trees in graphs and generalized connectivity, Networks, 55:4 (2010) 360–367.

[3] F. Fujie and P. Zhang, *Covering Walks in Graphs*, Springer Briefs in Mathematics, Springer, 2014.

Awards and Prizes:

- The 2008 Kirkman Medal (The Institute of Combinatorics and Its Applications)

Education and Appointments:

2007	Ph.D. in Mathematics, Western Michigan University
2007	Assistant Professor, University of Wisconsin La Crosse
2011	Associate Professor, University of Wisconsin La Crosse
2012	Associate Professor, Nagoya University

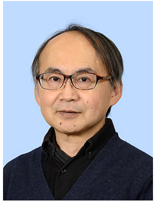
Message to Prospective Students:

Graph theory is a relatively new area of mathematics and has increased in popularity, perhaps partly due to the fact that introductory books usually contain many cute figures and interesting real-world applications. It is possible that one can jump in and start studying graph theory without having very deep background, so I welcome those students even if they are new to this field. Of course, however, that does not mean graph theory is easy! It is unlikely that one will be successful without having strong interest and dedication. Being strong in reading and writing would be another requirement; again, you do not have to be perfect from the beginning, but this is a heads-up. For those that want to learn the basics, here are some good books that cover standard topics:

[4] G. Chartrand, L. Lesniak, and P. Zhang, Graphs and Digraphs (CRC Press, 2010).

[5] J.A. Bondy and U.S.R. Murty, Graph Theory (Springer, 2008).

Finding good problems is as essential as becoming familiar with the subject. When one reads literature, remember to ask oneself questions such as how the given concepts can be generalized and what else can be explored.



Office: Rm 321 in Sci. Bldg. A
Phone: +81 (0) 52−789−2818 (ext. 2818)
Email: `fujiwara@math.nagoya-u.ac.jp`
Web-site: `no webpage available`

Membership of Academic Societies:
MSJ (The Mathematical Society of Japan)

Research Interest:

- Number Theory
- Arithmetic Algebraic Geometry
- Automorphic forms and Shimura varieties

Research Summary:

I am interested in themes which relate geometric viewpoint (arithmetic geometry) and analytic viewpoint (such as harmonic analysis on adeles). In particular, I am trying to understand non-abelian class field theory, which is a vast generalization of classical class field theory due to Teiji Takagi and Emil Artin.

Non-abelian class field theory is, after efforts of many mathematicians, now formulated as a correspondence between:

1. Galois representations (algebraic and geometric objects obtained mainly from algebraic varieties),
2. Automorphic representations (representation-theoretical interpretation of automorphic forms, which admit large discrete symmetries)

which is called as Langlands correspondence. This correspondence is expected to preserve L-functions defined on both sides (non-abelian reciprocity law), which yield highly non-trivial consequences in number theory.

Usually such a correspondence is obtained from a deep study of Shimura varieties. Now my interest is focused on:

1. Arithmetic geometry of Shimura varieties
2. Galois representations and p-adic Hecke algebras
3. Application of non-abelian class field theory to classical number theoretical problems

which are related to each other.

Major Publications:

[1] K. Fujiwara, Rigid geometry, Lefschetz trace formula and Deligne's conjecture, Inv. Math. **127** (1997), 489—533.

[2] K. Fujiwara, Galois deformations and arithmetic geometry of Shimura varieties, Proceedings of the International Congress of Mathematicians Madrid 2006 (2006), vol. 2, 347—371.

[3] K. Fujiwara and F. Kato, Rigid geometry and applications, Moduli spaces and Arithmetic Geometry, Advanced Studies in Pure Math. **45**, (2006), 327-386

Awards and Prizes:

- Algebra prize (1998), Mathematical Society of Japan

Education and Appointments:

1990 Assistant professor, University of Tokyo
1994 Lecturer, Nagoya University
1997 Associate professor, Nagoya University
2001 Professor, Nagoya University

Message to Prospective Students:

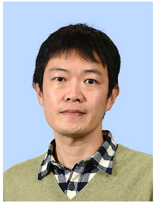
My main research area, number theory, has a long history. In any area which has a long history, one needs to learn many ideas and insights from the existing literature, before starting an actual research. The shortest way to understand it is, I think, to have a firm knowledge on basic notions. So I expect you to read foundational textbooks in algebra, geometry, and analysis.

At the same time, I strongly recommend to read research papers. In doing so, you will feel something, think deeply, and get inspirations. This is a route to study mathematics, especially for beginners.

My role is to offer you a technical support in mathematics. You are recommended to find your own mathematics, not mine. Mathematics is full of freedom.

To get an impression on the basic literature, please look at the following books.

[1] N. Bourbaki, Commutative Algebra, Chapters 1-7, Springer
[2] N. Bourbaki, General Topology, Chapters 1-4, Springer
[3] H. Hida, Elementary theory of L-functions and Eisenstein series, LMS.
[4] A. W. Knapp, Elliptic curves, Princeton Univ. Press.
[5] N. Koblitz, Introduction to elliptic curves and modular forms, Springer.
[6] J. P. Serre, Abelian ℓ-adic representations and elliptic curves, Research notes in Mathematics.



Office: Rm 455 in Sci. Bldg. A
Phone: +81 (0)52−789−2418 (ext. 2418)
Email: furusho@math.nagoya-u.ac.jp
Membership of Academic Societies:
MSJ (Mathematical Society of Japan)

Research Interest:

- Various fields related to number theory (particularly **Arithmetic Geometry** and **Arithmetic Topology**):

Research Summary:

My research is based on number theory. However it is not restricted to number theory, rather I am working on various fields related to number theory:

- **Arithmetic Geometry** is a part of number theory and **motive theory** is one of the most important theory in arithmetic geometry. Lots of people tend to regard that motive theory is a quite abstract and much general theory. But actually I am working oppositely on a very concrete side of motive theory, particularly on (p-adic) (multiple) zeta functions (p-adic) (multiple) polylogarithms and Knizhnik-Zamolodchikov equation. **Teichmüller-Lego philosophy** was posed by Grothendieck in his mysterious note 'Esquisse d'un programme' ('84). This philosophy is closely related to the above motive theory and also Drinfeld's subsequent works (in 80's) on quantum groups, where my research takes place. It has undergone a great interests due to appearance in different branches of mathematics, including motive theory, quantum group theory, deformation quantization theory, operad theory, analytic number theory, conformal field theory, differential geometry, low dimensional topology, mathematical physics, etc. It is one of the most exciting area to work today.
- **Arithmetic Topology** is a quite new area of mathematics, where I have started to work recently. It detects and purses several conceptual analogies between algebraic number theory and 3-dimensional topology (including **quantum topology**). One of the most impressive and advertising analogies might be the ones between primes and knots, which sound very mysterious and stimulating. Arithmetic topology is 'baby-like' because it has just started and is waiting to be developed. It is really a good time to get started pioneering works for younger generations like you!

Major Publications:

[1] H. Furusho, Double shuffle relation for associators, *Annals of Mathematics, Vol. 174 (2011), No. 1, 341-360.*

[2] H. Furusho, Pentagon and hexagon equations, *Annals of Mathematics, Vol. 171 (2010), No. 1, 545-556.*

[3] H. Furusho, p-adic multiple zeta values I – p-adic multiple polylogarithms and the p-adic KZ equation, *Inventiones Mathematicae, Volume 155, Number 2, 253-286, (2004).*

Awards and Prizes:

- 2014, Algebra Prize of Math. Soc. Japan.
- 2007, Inoue Research Award for Young Scientists.
- 2004, Takebe Prize of Math. Soc. Japan.

Education and Appointments:

2018 – Now	Professor at Nagoya University, Nagoya, Japan.
2017	Institut de Rechérche Mathématique Avancee, Strasbourg university, Strasbourg, France.
2010 – 2018	Associate Professor at Nagoya University, Nagoya, Japan.
2013	Isaac Newton Institute for Mathematical Sciences, Cambridge, UK.
2013	Max Planck Institute for Mathematics, Bonn, Germany.
2007 – 2009	École Normale Supérieure, Paris, France.
2004 – 2005	Institute for Advanced Study, Princeton, USA.
2004 – 2010	Assistant Professor at Nagoya University, Nagoya, Japan.
2003	Ph.D from RIMS, Kyoto, Japan.

Message to Prospective Students:

For undergraduate students; please be familiar with the standard techniques in number theory by reading, for example,

- J.P. Serre, "A Course in Arithmetic", *Graduate Texts in Mathematics, 67, Springer-Verlag.*

For master course students; it is important to learn several theories other than number theory if you want to work with me. The followings might be good to learn arithmetic topology.

- S. Chmutov, S. Duzhin, J. Mostovoy, "Introduction to Vassiliev knot invariants",*Cambridge University Press.*
- C. Kassel, "Quantum Groups",*Graduate Texts in Mathematics, 155. Springer-Verlag.*
- T. Ohtsuki, "Quantum Invariants",*Series on Knots and Everything, 29. World Scientific.*
- M. Morishita, "Knots and primes", *Universitext. Springer, London, 2012.*

But before you will contact with me, please find by yourself the literatures (other than the above mentioned books if possible!) which you want to read with me during the master course and also be prepared to explain me your mathematical perspectives.

For doctor course students; the following are the paper which I like most. Make a challenge to read one of the following papers:

- P. Deligne, "Le groupe fondamental de la droite projective moins trois points", *Galois groups over Q, 79–297, Math. Sci. Res. Inst. Publ., 16, Springer, New York, (1989).*
- V.G. Drinfel'd, "On quasitriangular quasi-Hopf algebras and on a group that is closely connected with $\mathrm{Gal}(\overline{Q}/Q)$", *Leningrad Math. J. 2 (1991), no. 4, 829–860.*
- M. Kontsevich, "Operads and motives in deformation quantization", *Lett. Math. Phys. 48 (1999), no. 1, 35–72.*

Once you start to read, you will soon realized that it is really hard to read. But they are really enriched papers. I wish to educate perspective students for years to overcome them.

Good Luck!

Office: Rm 327 in Sci. Bldg. A
Phone: +81 (0) 52−789−2408 (ext. 2408)
Email: hamanaka@math.nagoya-u.ac.jp
Web-site: http://www2.yukawa.kyoto-u.ac.jp/~masashi.hamanaka/
Membership of Academic Societies:
The Physical Society of Japan (JPS),
The Mathematical Society of Japan (MSJ)

Research Interest:

- Mathematical Physics
- Gauge Theory related to String Theory
- Noncommutative Solitons

Research Summary:

For the last several years, I have studied extension of soliton theories and integrable systems to noncommutative spaces. In gauge theories, the noncommutative extension corresponds to introduction of background flux and has been applied to the corresponding physical situations such as the quantum Hall effects in background magnetic flux. Furthermore, in noncommutative spaces, singularities could be resolved and therefore new physical (smooth) objects could appear. For example, $U(1)$ instantons are one of such new objects which come from resolution of singularity in the (instanton) moduli spaces of the anti-self-dual Yang-Mills equations in four dimensional noncommutative Euclidean spaces. This is also due to the fact that the ADHM construction can work well in the noncommutative settings, and in this sense, integrability is also preserved (e.g. [1]).

Noncommutative solitons actually describe D-branes themselves in some D-brane configurations, which makes us to analyze various properties of D-branes by analyzing those of noncommutative solitons. The latter is sometimes much easier than the former and long-standing problems on D-branes such as Sen's conjecture have been exactly solved.

After the development of noncommutative solitons in the effective theories of D-branes which are gauge theories, noncommutative extension of lower-dimensional soliton equations (e.g. KdV eq. in scalar theories) had been also studied intensively (e.g. [2]). In [3], it is proved that many of such lower-dimensional noncommutative soliton equations can be derived from the 4-dimensional noncommutative anti-self-dual Yang-Mills equation by reduction. This result implies that the lower-dimensional soliton equations also belong to gauge theories in this context, and hence have the corresponding physical situations with background flux. These soliton equations can be embedded to the $N = 2$ strings and can be applied to them via analysis of the exact soliton solutions.

In [4], we find a Bäcklund transformation for the noncommutative anti-self-dual Yang-Mills equation and construct wide class of new solutions including not only noncommutative instantons but non-linear plane-wave (domain-wall type) solutions. In the construction of the solutions, the quasideterminants play cricial roles and simplify proofs in the commutative case. (For a survey of quasideterminants, see, e.g. [math/0208146].) This is in common with the lower-dimensional soliton equations (e.g. [5]). I look for a universal and essential structure and formulation of integrable systems from the viewpoint of the quasideterminants.

Major Publications:

[1] M. Hamanaka and T. Nakatsu, "Noncommutative Instantons and Reciprocity," in preparation. (For a survey, see [arXiv:1311.5227].)

[2] M. Hamanaka, "Noncommutative Solitons and Integrable Systems," hep-th/0504001.

[3] M. Hamanaka, "Noncommutative Ward's Conjecture and Integrable Systems," Nuclear Physics B **741** (2006), 368 – 389 [hep-th/0601209].

[4] C. R. Gilson, M. Hamanaka and J. J. C. Nimmo, "Bäcklund Transformations and the Atiyah-Ward ansatz for Noncommutative Anti-Self-Dual Yang-Mills Equations," Proceedings of the Royal Society A **465** (2009), 2613 – 2632 [arXiv:0812.1222].

[5] M. Hamanaka, "Noncommutative Integrable Systems and Quasideterminants," AIP Conf. Proc. **1212**, 122 (2010) [arXiv:1012.6043].

Education and Appointments:

2003/3	Ph.D at the University of Tokyo, Department of Physics
2003/4	JSPS postdoctoral fellow at the Univ. of Tokyo (Komaba)
2004/2	Assistant Professor, Nagoya University
	(2005/8-2006/12: Visiting Researcher, Univ. of Oxford)
	(2008/10-2009/2: Visiting Researcher, Univ. of Glasgow)
	(2009/2-2009/3: Visiting Researcher, IHES, France)
2016/4	Associate Professor, Nagoya University

Message to Prospective Students:

I would be interested in mathematical structure behind the fundamental law of nature, currently, quantum field theory and string theory. Any student is welcome to discuss with me. (Please note that I am not a mathematician but a physicist.)

So far, I have been an adviser of seven graduate students. In the case of a main adviser, I have had a meeting or an informal seminar to help them once per one or two weeks. The following lists are a part of the relevant papers including collaborations with my students (underlined).

[1] P. Etingof, I. Gelfand and V. Retakh, "Factorization of differential operators, quasideterminants, and nonabelian Toda field equations," Math. Res. Lett. **4**, 413 (1997) [q-alg/9701008].

[2] K. Ueno and K. Takasaki, "Toda lattice hierarchy," Adv. Stud. Pure Math. **4**, 1 (1984).

[3] S. A. Cherkis and R. S. Ward, "Moduli of Monopole Walls and Amoebas," JHEP **1205**, 090 (2012) [arXiv:1202.1294].

[4] M. Hamanaka, H. Kanno and D. Muranaka, "Hyperkähler metrics from monopole walls," Phys. Rev. D **89**, 065033 (2014) [arXiv:1311.7143].

[5] S. A. Cherkis, "Octonions, Monopoles, and Knots," Lett. Math. Phys. **105**, 641 (2015) [arXiv:1403.6836].

[6] M. Hamanaka and H. Okabe, "Soliton Scattering in Noncommutative Spaces," Theor. Math. Phys. **197**, 1451-1468 (2018) [arXiv:1806.05188].

[7] L. J. Mason and N. M. Woodhouse, *Integrability, Self-Duality, and Twistor Theory* (Oxford UP, 1996) [ISBN/0-19-853498-1].

[8] C. R. Gilson, M. Hamanaka, S. C. Huang and J. J. C. Nimmo, "Soliton solutions of noncommutative anti-self-dual Yang–Mills equations," J. Phys. A **53**, 404002 (2020) [arXiv:2004.01718].

[9] M. Hamanaka and S. C. Huang, "New Soliton Solutions of Anti-Self-Dual Yang-Mills equations," JHEP **10**, 101 (2020) [arXiv:2004.09248].

[10] M. Hamanaka, S. C. Huang and H. Kanno, "Solitons in Open N = 2 String Theory," PTEP **2023, 4**, 043B03 (2023) [arXiv:2212.11800].

Office: Rm 355 in Sci. Bldg. A

Phone: +81 (0) 52−789−2549 (ext. 2549)

Email: masahito@math.nagoya-u.ac.jp

Web-site: http://www.math.nagoya-u.ac.jp/~masahito/index_e.html

Membership of Academic Societies:

IEEE (The Institute of Electrical and Electronics Engineers), The Mathematical Society of Japan, JPS (The Physical Society of Japan), IEICE (The Institute of Electronics, Information and Communication Engineers)

Research Interest:

- Quantum Information Theory
- Quantum Cryptography
- Information Theory
- Non-equilibrium Statistical Physics for Closed System

Research Summary:

My research area is mathematical theory for information and its application, especially, I have studied mathematical theory for communication, statistical inference, and cryptography. These topics have different applied aspects, and have different communities due to their historical reason. However, these topics have common mathematical aspects. Hence, a common mathematical treatment is possible for these topics. I have investigated these topics based on the common mathematical properties. In particular, I have studies these topics mainly for quantum systems but also for non-quantum (classical) system. Recently, using this method, I study the foundation of thermodynamics.

Recently, I am mainly studying the following points. One is mathematical treatment for quantum information processing based on group representation theory. Group symmetry simplifies many kinds of problems in quantum systems by removing the basis dependence. In fact, even if a given information processing problem requires a difficult analysis due to the complexity of the problem, the group symmetry simplifies the problem by reducing the complexity. Using the group symmetry, we can construct universal protocols that works independently of the basis. Since the group-theoretical approach to quantum systems are not finished, further developments are required. The second is mathematical theory for information-theoretical secrecy. Recently, I have proposed several approaches for this topic, however, their relations are not so clear and several problems still remain open. Thus, further researches are required for this topic. The third is the information theory for Markov chain. This topic can be treated via Perron-Frobenius theorem. Finally, I am also working on non-equilibrium statistical physics for closed system, which refines thermo dynamics.

Major Publications:

[1] M. Hayashi and H. Nagaoka, "General formulas for capacity of classical-quantum channels," IEEE Transactions on Information Theory, **49** (2003), no. 7, 1753-1768.

[2] M. Hayashi, "Upper bounds of eavesdropper's performances in finite-length code with the decoy method," Physical Review A, **76**, (2007), 012329.

[3] M. Hayashi, "Universal coding for classical-quantum channel," Communications in Mathematical Physics **289** (2009), no. 3, 1087-1098.

[4] M. Hayashi, "Information Spectrum Approach to Second-Order Coding Rate in Channel Coding," IEEE Transactions on Information Theory, **55** (2009), no. 11, 4947 - 4966.

Awards and Prizes:

- *2015 JSPS PRIZE:* "Information Theory and Quantum Information Theory for Finite-Coding-Length"
- *2011 IEEE Information Theory Society Paper Award:* "Information Spectrum Approach to Second-Order Coding Rate in Channel Coding" *IEEE Transactions on Information Theory*, Vol. 55, No. 11, 4947 - 4966 (2009). This prize is the most distinguished paper award in the information theory community.
- Japan IBM prize in the computer science section 2010: "Universal protocol in quantum information and its application to quantum key distribution" This prize is one of the most distinguished prizes in Japan among information science for researchers across Japan under 45.
- Funai Foundation for Information Technology Award in the computer science category 2010: "Universal quantum information protocol and its application to quantum cryptography"
- 2001 SITA Encouragement Award (by The Society of Information Theory and its Applications (SITA)): "Variable length universal entanglement concentration by local operations"

Education and Appointments:

1998	JSPS Research Fellow at Kyoto University
2000	Researcher, Brain Science Institute, RIKEN
2003	Research Manager, ERATO Quantum Computation and Information Project, Japan Science and Technology Agency
2007	Associate Professor, Tohoku University
2012	Professor, Nagoya University

Message to Prospective Students:

The following are candidates of topic for Master course:

> Quantum information theory, Quantum cryptography, Quantum statistical inference, Information theory.

Since these topics are linked to each other, it is possible to tackle one topic based on knowledge obtained from another topic. The following texts are useful for these topics.

- M. A. Nielsen, I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press (2000).
- M. Hayashi, *Quantum Information: An Introduction*, Springer (2006).
- M. Hayashi, S. Ishizaka, A. Kawachi, G. Kimura, and T. Ogawa, *Introduction to Quantum Information Science*, Graduate Texts in Physics, Springer (2014).

Since quantum information is a new area, students can relatively easily publish their own research article while the possibility depends on their efforts and their ability. Required preliminary knowledge is level 1, which corresponds to the contents for first, second, and third year courses. In particular, I ask students to master linear algebra, calculus, and elementary probability, which contains the central limit theorem but does not necessarily contain measure theory, because they are very important for these topics. Since these topics are opened to other research area, students are required to study topics outside of mathematics. Since the above research topics are applied to practical problems, it is required not only to understand mathematically formulated problems but also to grasp the target problem itself. For doctoral course, I can supervise group-theoretical approaches to the above topics as well as the above topics themselves.

Office: Rm 443 in Sci. Bldg. A
Phone: +81 (0) 52−789−2416 (ext. 2416)
Email: hayashi@math.nagoya-u.ac.jp

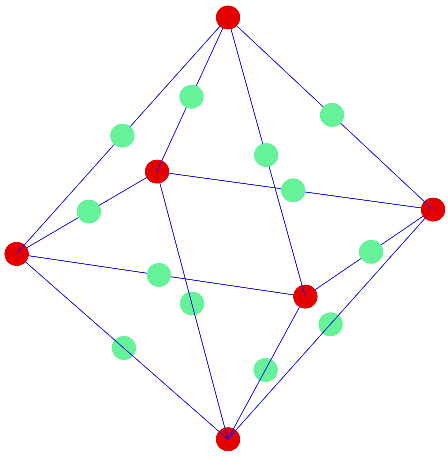
Membership of Academic Societies:
Mathematical Society of Japan

Research Interest:

- Hopf algebras and their generalizations
- Reprentations of quantum groups
- Tensor categories

Research Summary:

I am currently interested in Hopf algebras and their generalizations, such as face algebras, weak Hopf algebras and Hopf algebebroids. These structures relate to many area of mathematics and mathemacical physics, including, low dimensional topology, operator algebras, Yang-Baxter equations and conformal field theory.



Major Publications:

[1] T. Hayashi, Sugawara operators and Kac-Kazhdan conjecture, Invent. Math., **94** (1988), no. 1, 13-52.

[2] T. Hayashi, Quantum group symmetry of partition functions of IRF models and its application to Jones' index theory, Commun. Math. Phys., **157** (1993), 331-345.

[3] T. Hayashi, Coribbon Hopf (face) algebras generated by lattice models. J. Algebra, **233** (2000), 614–641.

[4] T. Hayashi, A brief introduction to face algebras, in New trends in Hopf algebra theory, La Falda 1999, Contemp. Math. 267, Amer. Math. Soc., 2000, pp. 161-176.

Education and Appointments:

1988 Assistant, Nagoya University
1995 Assistant Professor, Nagoya University

Message to Prospective Students:

The following is a list of possible text books for Small Group Class (Seminar).

[1] C. Kassel, Quantum Groups, Graduate texts in Mathematics 155, Springer-Verlag, 1995.

[2] D. E. Radford, Hopf Algebras, World Scientific, 2012.

[3] J. Hong and S.-J. Kang, Introduction to Quantum Groups and Crystal Bases, Amer. Math. Soc., 2002.

[4] J. C. Jantzen, Lectures on Quantum Groups, American Mathematical Society, 1996.

[5] V. G. Kac, Infinite-Dimensional Lie Algebras, 3rd ed., Cambridge Univ. Press, 1990.

Office: Rm 449 in Sci. Bldg. A
Phone: +81 (0) 52−789−2547 (ext. 2547)
Email: larsh@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~larsh/

Membership of Academic Societies:
American Mathematical Society
European Mathematical Society
Danish Mathematical Society

Research Interest:

- Algebraic K-Theory
- Equivariant Homotopy Theory
- p-Adic Arithmetic Geometry

Research Summary:

My area of specialization is algebraic K-theory and algebraic topology, in general, and topological cyclic homology and equivariant stable homology theory, in particular. As homological algebra came about because of the fact that not every module is projective, algebraic K-theory came about because of the fact that not every projective module is free. That is, homological algebra and algebraic K-theory are necessary in order to do linear algebra over a ring that is not a field. Such rings appear in all brances of mathematics, e.g. the coordinate ring of scheme in algebraic geometry and number theory and the integral and spherical group rings of a discrete group in geometric topology.

Despite the name, algebraic K-theory does not admit a purely algebraic definition. Instead, following Quillen, the algebraic K-groups of a ring R are defined to be the homotopy groups

$$K_n(R) = \pi_n(K(R))$$

of a (pointed) topological space $K(R)$ built by gluing together simplices in a way that reflects the structure of the category of finitely generated projective right R-modules. To understand the structure of these groups is a very deep problem indeed. For instance, the statement that $K_{4m}(\mathbb{Z}) = 0$ for all positive integers m is equivalent to the Kummer-Vandiver conjecture in number theory which states that no prime number p divides the class number of the field $\mathbb{Q}(\zeta_p + \zeta_p^{-1})$. (The conjecture is known to hold for $p < 163,000,000$.) The cyclotomic trace map, which is a generalization of the classical Chern character, is a natural map from algebraic K-theory to a topological refinement of Connes' cyclic homology defined by Bökstedt-Hsiang-Madsen. It is an important tool for understanding algebraic K-theory. Indeed, for non-regular rings, it is currently the only tool available. For instance, it is proved in the paper [1] that if $\mathcal{O}_K$ a complete discrete valuation ring with quotient field $K = \mathcal{O}_K[1/p]$ of characteristic 0 and algebraically closed residue field $k = \mathcal{O}_K/\mathfrak{m}_K$ of odd characteristic p, then there is the following canonical isomorphism.

$$K_*(K, \mathbb{Z}/p\mathbb{Z}) \to (W\Omega^*_{\mathcal{O}_K}(\log \mathfrak{m}_K) \otimes S_{\mathbb{Z}/p\mathbb{Z}}(\mu_p))^{F=1}$$

To formulate this result, it was necessary to define the de Rham-Witt complex with log poles that appear on the right-hand side. In this way, understanding the structure of algebraic K-theory often necessitates the creation of new mathematics. Motivic cohomology is another example of new mathematics that was created in this way.

Major Publications:

[1] L. Hesselholt and I. Madsen, On the K-theory of local fields, Ann. of Math. **158** (2003), 1–113.

[2] T. Geisser and L. Hesselholt, The de Rham-Witt complex and p-adic vanishing cycles, J. Amer. Math. Soc. **19** (2006), 1–36.

[3] T. Geisser and L. Hesselholt, Bi-relative algebraic K-theory and topological cyclic homology, Invent. Math. **166** (2006), 359–395.

[4] L. Hesselholt, On the p-typical curves in Quillen's K-theory, Acta Math. **177** (1996), 1–53.

[5] L. Hesselholt and I. Madsen, Cyclic polytopes and the algebraic K-theory of truncated polynomial algebras, Invent. Math. **130** (1997), 73–97.

Awards and Prizes:

- Alfred P. Sloan Fellowship (1998)
- Foreign Member of the Royal Danish Academy of Sciences and Letters (2012)
- Niels Bohr Professor (2013–2018)
- Clay Senior Scholar (2014)

Education and Appointments:

1994	Institut Mittag-Leffler Postdoctoral Fellow
1994	C.L.E. Moore Instructor, M.I.T.
1997	Assistant Professor, M.I.T.
2001	Associate Professor, M.I.T.
2008	Professor, Nagoya University

Message to Prospective Students:

The research area of algebraic K-theory is suitable for students with strong interest and background in algebra, number theory, and homotopy theory. It is an area that intersects numerous mathematical fields and for that reason it is necessary to learn a lot of background material before starting cutting-edge research. For that reason, it is important that students are capable of reading books and research papers independently. Here is a representative list of books and articles:

[1] D. Quillen, Homotopical algebra, Lecture Notes in Math. 43, Springer, Berlin 1967.

[2] D. Quillen, Higher algebraic K-theory. I. *Algebraic K-theory, I: Higher K-theories (Proc. Conf., Battelle Memorial Inst., Seattle, WA, 1972)*, pp. 85–147. Lecture Notes in Math., 341, Springer, Berlin 1973.

[3] F. Waldhausen, Algebraic K-theory of spaces. *Algebraic and geometric topology (New Brunswick, N.J., 1983)*, 318?419, Lecture Notes in Math., 1126, Springer, Berlin, 1985.

[4] J. Milnor, Introduction to algebraic K-theory. Annals of Mathematics Studies, 72. Princeton University Press, Princeton, N.J., 1971.

Office: Rm 501 in Math. Bldg.
Phone: +81 (0) 52−789−2432 (ext. 2432)
Email: hirai.hiroshi@math.nagoya-u.ac.jp
Web-site: https://www.math.nagoya-u.ac.jp/~hirai.hiroshi/index.html

Membership of Academic Societies:
The Japan Society for Industrial and Applied Mathematics (JSIAM) ,
The Operations Research Society of Japan (ORSJ)

Research Interest:

- Optimization
- Algorithm
- Discrete Mathematics

Research Summary:

Discrete optimization (or combinatorial optimization) is a mathematical theory that aims at designing algorithms to find the most desirable one among a finite but huge number of combinations in a realistic time. The theory of discrete optimization began in the mid-1960s with a series of studies by J. Edmonds, in which he proposed the thesis of "*efficient algorithm* ≒ *polynomial-time algorithm*," introduced *polyhedral methods*, and showed the importance of *matroids* and *submodular functions* in algorithm design. The polyhedral method is one of the basic paradigms of algorithm design, which is "*to design an algorithm from the viewpoint of continuous optimization by embedding a discrete optimization problem into a convex optimization problem in Euclidean space.*" While many discrete optimization problems are NP-hard, understanding the class P of problems with polynomial-time algorithms remains an important challenge. Matroids and submodular functions, which are closely related to class P, are recognized as discrete convex sets and functions, and have evolved into the theory of convex analysis on integer lattice points—*discrete convex analysis*—.

I worked on multi-commodity extensions of Ford-Fulkerson's maximum flow minimum-cut theorem in network flow problem [1], and polynomial-time solvability classification of facility location problems that generalizes the minimum cut problem [2]. These studies deal with discrete convex optimization on special graph structures, and I found that they can be embedded as geodesically convex optimization on nonpositively curved metric spaces (CAT(0)-spaces) [3]. I then obtained the idea of "developing convex optimization/algorithm theory for nonpositively curved spaces, and applying it to discrete optimization", which updates the above paradigm. Since then, I have been conducting research based on this idea. Recently, I focus on the following two themes.

The first is *Edmonds problem*, that is the symbolic rank compution of matrices containing variables. Although it is a fundamental problem with many applications, the existence of deterministic polynomial-time algorithms is an important open problem in theoretical computer science. Also it may be called *algebraic combinatorial optimization*, since it generalizes a class of combinatorial optimization problems such as bipartite matching and linear matroid intersection. Recently, a noncommutative version of Edmonds problem was introduced, in which the variables are *noncommutative*. It was shown that the rank (*noncommutative rank*) in this setting can be computed in polynomial time. The computation of the noncommutative rank becomes a new type of optimization problem over the family of vector subspaces. I have developed a polynomial-time algorithm using convex optimization of a non-manifold CAT(0) space [8]. I further generalized it to a weighted version (degree computation of noncommutative determinants) [5].

The second is study of convex optimization on Hadamard manifolds and symmetric spaces. The noncommutative Edmonds problem over $\mathbb{C}$, which can also be formulated as a norm minimization problem over an orbit of group action, becomes convex optimization on symmetric spaces of nonpositive curvature. Various other applications have been found. While studying differential geometry, I am trying to develop convex analysis and interior point methods on such manifolds [9, 10].

I have also studied discrete structures such as lattices, matroids, buildings, and discrete metric spaces due to my interest as stages for discrete optimization [4, 6, 7].

For more information on my research, please visit my web page.

Major Publications:

[1] H. Hirai: The maximum multiflow problems with bounded fractionality, *Mathematics of Operations Research* **39** (2014), 60–104.

[2] H. Hirai, Discrete convexity and polynomial solvability in minimum 0-extension problems, *Mathematical Programming, Series A* **155**, (2016) 1–55.

[3] H. Hirai: L-convexity on graph structures, *Journal of the Operations Research Society of Japan* **61** (2018), 71–109.

[4] H. Hirai: Uniform semimodular lattices and valuated matroids, *Journal of Combinatorial Theory, Series A* **165** (2019), 325–359.

[5] H. Hirai: Computing the degree of determinants via discrete convex optimization on Euclidean buildings, *SIAM Journal on Applied Algebra and Geometry* **3** (2019), 523–557.

[6] J. Chalopin, V. Chepoi, H. Hirai and D. Osajda: Weakly modular graphs and nonpositive curvature, *Memoirs of the AMS* **268**, no.1309, (2020).

[7] H. Hirai: A nonpositive curvature property of modular semilattices, *Geometriae Dedicata* **214** (2021), 427–463.

[8] M. Hamada and H. Hirai: Computing the nc-rank via discrete convex optimization on CAT(0) spaces, *SIAM Journal on Applied Geometry and Algebra* **5** (2021), 455–478.

[9] H. Hirai: Convex analysis on Hadamard spaces and scaling problems, *Foundations of Computational Mathematics*, to appear.

[10] H. Hirai, H. Nieuwboer, and M. Walter: Interior-point methods on manifolds: theory and applications, FOCS 2023, to appear.

Awards and Prizes:

- 2014, Research Award, The Operations Research Society of Japan.
- 2018, The Young Scientists' Award, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology.

Education and Appointments:

2004	Master of Information Science and Technology, Graduate School of Information Science and Technology, The University of Tokyo
2004	Research Associate, Research Institute for Mathematical Sciences, Kyoto University
2007	Assistant Professor, Research Institute for Mathematical Sciences, Kyoto University
2010	Lecturer, Graduate School of Information Sciences and Technology, The University of Tokyo
2014	Associate Professor, Graduate School of Information Sciences and Technology, The University of Tokyo
2023	Professor, Graduate School of Mathematics, Nagoya University

Message to Prospective Students:

In the small group seminar, you will study the following basic textbooks on optimization and algorithms, and tackle specific problems according to your interests.

[1] S. Boyd and L. Vandenberghe: *Convex Optimization*, Cambridge University Press, 2004.

[2] J. Kleinberg and E. Tardos: *Algorithm Design*, Pearson, 2006.

I expect that you will find interesting research directions if you review various problems in mathematical science from the viewpoints of optimization, algorithms, and computational complexity.

Office: Rm 507 in Math. Bldg.
Phone: +81 (0) 52−789−4838 (ext. 4838)
Email: hishida@math.nagoya-u.ac.jp
Membership of Academic Societies:
Mathematical Society of Japan

Research Interest:

- Nonlinear partial differential equations
- Navier-Stokes system

Research Summary:

My research interest is focused on nonlinear partial differential equations (PDEs) arising from fluid mechanics. The motion of the fluid is essentially nonlinear on the one hand and analysis is often involved even at the level of linearized systems (around a basic state) on the other. Furthermore, some qualitative properties, such as asymptotic structure at spatial/temporal infinity, of solutions could depend on the fluid region and on the motion of obstacles immersed there. Mathematical analysis of the Navier-Stokes system is traced back to a series of celebrated papers by Leray in 1930s. Later on, remarkable progress has been made by a lot mathematicians and it has always had much influence on analysis of some other PDEs. In spite of their efforts since the landmark by Leray, the following problem still remains open: The unique existence of regular solution globally in time without any smallness assumption on initial data no matter how smooth they are. Besides this, however, we have many other challenging problems, in particular, it is of utmost importance to find mathematical properties (asymptotic structure, stability, attainability,...) of flows arising in physically relevant situations, such as the flow past/around a rotating obstacle [1, 2, 4, 5, 9] and even fluid-structure interaction [3, 8].

Major Publications:

[1] T. Hishida, Spatial pointwise behavior of time-periodic Navier-Stokes flow induced by oscillation of a moving obstacle, *J. Math. Fluid Mech.* **24** (2022), Paper No.102.

[2] T. Hishida and M. Kyed, On the asymptotic structure of steady Stokes and Navier-Stokes flows around a rotating two-dimensional body, *Pacific J. Math.* **315** (2021), 89–109.

[3] T. Hishida, A. Silvestre and T. Takahashi, Optimal boundary control for steady motions of a self-propelled body in a Navier-Stokes liquid, *ESAIM: Control, Optimisation and Calculus of Variations* **26** (2020), Paper No.92.

[4] T. Hishida, Decay estimates of gradient of a generalized Oseen evolution operator arising from time-dependent rigid motions in exterior domains, *Arch. Rational Mech. Anal.* **238** (2020), 215–254.

[5] T. Hishida, Large time behavior of a generalized Oseen evolution operator, with applications to the Navier-Stokes flow past a rotating obstacle, *Math. Ann.* **372** (2018), 915–949.

[6] T. Hishida, Stationary Navier-Stokes flow in exterior domains and Landau solutions, *Handbook of Mathematical Analysis in Mechanics of Viscous Fluids* 299–339, Springer, 2018.

[7] T. Hishida and P. Maremonti, Navier-Stokes flow past a rigid body: attainability of steady solutions as limits of unsteady weak solutions, starting and landing cases, *J. Math. Fluid Mech.* **20** (2018), 771–800.

[8] T. Hishida, A. Silvestre and T. Takahashi, A boundary control problem for the steady self-propelled motion of a rigid body in a Navier-Stokes fluid, *Annales de l'Institut Henri Poincare / Analyse non lineaire* **34** (2017), 1507–1541.

[9] T. Hishida, Mathematical analysis of the equations for incompressible viscous fluid around a rotating obstacle, *Sugaku Expositions* **26** (2013), 149–179.

[10] T. Hishida, The nonstationary Stokes and Navier-Stokes flows through an aperture, *Contributions to Current Challenges in Mathematical Fluid Mechanics*, 79–123, *Adv. Math. Fluid Mech.*, Birkhäuser, Basel, 2004.

[11] T. Hishida, An existence theorem for the Navier-Stokes flow in the exterior of a rotating obstacle, *Arch. Rational Mech. Anal.* **150** (1999), 307–348.

Awards and Prizes:

- Analysis Prize (2007)

Education and Appointments:

1993	Dr. Sci., Waseda University
1993	Research Associate, Waseda University
1994	Research Associate, Kumamoto University
1997	Assistant Professor, Niigata University
2000	Associate Professor, Niigata University
2008	Professor, Nagoya University

Message to Prospective Students:

As the subject in the seminar of master course, I can propose, for instance, (1) elliptic PDEs of second order; (2) the method of functional analysis such as semigroup theory; (3) large time behavior of solutions to evolution equations by means of spectral analysis; (4) mathematical analysis of the Navier-Stokes system, which are related with each other. As the textbook, I would recommend

1. L. C. Evans, Partial Differential Equations, Amer. Math. Soc., 1998.
2. D. Gilbarg and N. S. Trudinger, Elliptic Partial Differential Equations of Second Order, Springer, 1977.
3. H. Sohr, The Navier-Stokes Equations, An Elementary Functional Analytic Approach, Birkhäuser, 2001.
4. G. P. Galdi, An Introduction to the Mathematical Theory of the Navier-Stokes Equations, Steady Problems, Second Edition, Springer, 2011.
5. T.-P. Tsai, Lectures on Navier-Stokes Equations, Amer. Math. Soc., 2018.

For those who wish to proceed to the doctor course, they are asked to read some related papers. In the doctor course, what is important is to find a problem and to develop analysis by himself/herself. It might be better to work on a bit different subject from mine.

Office: Rm 425 in Sci. Bldg. A
Phone: +81 (0) 52−789−5594 (ext. 5594)
Email: itoken@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~itoken/
Membership of Academic Societies:
Mathematical Society of Japan

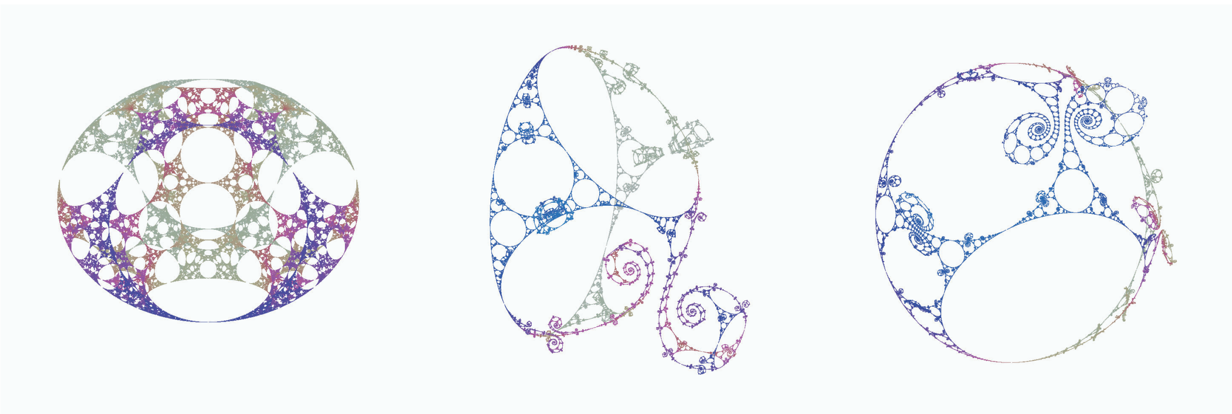
Research Interest:

- Hyperbolic geometry, conformal Geometry
- Kleinian groups, Riemann surfaces, Teichmüller theory
- Low-dimensional topology

Research Summary:

My major research interest is hyperbolic geometry. Especially I am interested in hyperbolic 3-manifolds and their deformation spaces. A hyperbolic 3-manifold is obtained as the quotient manifold of the hyperbolic 3-space by the action of a Kleinian group, a discrete subgroup of $\mathrm{PSL}(2,\mathbb{C})$. The boundary of the deformation space of a Kleinian group has fractal structure, and is very complicated. I am eager to understand the 'complexity' of the boundaries of these spaces.

I also interested in higher dimensional Kleinian groups, especially 4-dimensional Kleinian groups acting on the hyperbolic 4-space. In this case, limit sets of Kleinian groups are fractal objects in 3-sphere. Figures below are computer-generated limit sets of 4-dimensional Kleinian groups with two generators.



Major Publications:

[1] K. Ito, *Convergence and divergence of Kleinian punctured torus groups,* Amer. J. Math. 134 (2012), 861–889.

[2] Y. Araki and K. Ito, *An extension of the Maskit slice for 4-dimensional Kleinian groups,* Conform. Geom. Dyn. 12 (2008), 199–226.

[3] K. Ito, *On continuous extensions of grafting maps,* Trans. Amer. Math. Soc. 360 (2008), 3731–3749.

[4] K. Ito, *Exotic projective structures and quasi-Fuchsian space, II,* Duke Math. J. 140 (2007), 85–109.

[5] K. Ito, *Schottky groups and Bers boundary of Teichmuller space,* Osaka J. Math. 40 (2003), 639–657.

[6] K. Ito, *Exotic projective structures and quasi-Fuchsian space,* Duke Math. J. 105 (2000), 185–209.

Education and Appointments:

2000 Ph.D. at Tokyo Institute of Technology
2000 Assistant Professor, Nagoya University
2007 Associate Professor, Nagoya University

Message to Prospective Students:

Some basic references of this area are [1], [2] and [3]. More advanced topics can be found in [4], [5], [6] and [7]. Especially [5] is the best reference to get an impression of this area. Some master course students used [3], [8], [9] and [10] as textbooks of seminar. [11] will be used in the forthcoming master course seminar. [12] is a good guidebook for drawing computer graphics as in the previous page. Sutudentswho are interested in such computer graphics are also welcome.

[1] S. Katok, Fuchsian Groups, The University of Chicago Press, 1992.

[2] F. Bonahon, Low-dimensional geometry: from euclidean surfaces to hyperbolic knots, AMS, 2009.

[3] A. F. Beardon, The geometry of Discrete Groups, Springer GTM 91, 1983.

[4] A. Marden, Outer Circles, Cambridge University Press, 2007.

[5] K. Matsuzaki and M. Taniguchi, Hyperbolic Manifolds and Kleinian Groups, Oxford Science Publications, 1998.

[6] Y. Imayoshi and M. Taniguchi, An Introduction to Teichmüller Spaces, Springer, 1992.

[7] A. Fathi, F. Laudenbach and V. Poenaru, (translated by D. M. Kim and D. Margalit) Thurston's work on surfaces, Princeton University Press 2012.

[8] K. Stephenson, Introduction to Circle Packing, Cambridge University Press, 2005.

[9] P. J. Nocholls, The Ergodic Theory of Discrete Groups, Cambridge University Press, 1989.

[10] F. Dal'Bo, Geodesic and Horocyclic Trajectories, Springer, 2011.

[11] B. Farb and D. Margalit, A Primer on Mapping Class Groups, Princeton University Press, 2012.

[12] D. Mumford, C. Series, D. Wright, Indra's Pearls, Cambridge University Press, 2002.

Office: Rm 502 in Math. Bldg.
Phone: +81 (0)52–789–5599 (ext. 5599)
Email: izumi@math.nagoya-u.ac.jp

Membership of Academic Societies:
The Physical Society of Japan (JPS)

Research Interest:

- Gravitational theory
- Cosmology

Research Summary:

I am working on gravitational theory. My final purpose is the construction of the quantum theory of gravity.

General relativity, proposed by A. Einstein, is the fundamental theory of classical gravity. This theory has mathematically interesting aspects, and thus many researchers are investigating its mathematical structure. Moreover, general relativity is an excellent theory in physics since no conflicts with experimental results and observational facts have been found.

Although general relativity is an excellent theory of classical gravity, there is a problem; "its straightforward quantization does not work well." Since the fundamental physics except gravity is described as quantum theory, the quantization of gravity theory is required to unify all theories of fundamental physics. Because the quantization of general relativity doesn't go well, by modifying or extending general relativity (or also modifying the quantum theory) many researchers try to construct the unified theory describing all physical phenomenon. The strong candidate is the super string theory.

Toward the construction of quantum gravity theory, we have the following three topics to work on;

- Investigating the mathematical structures of fundamental classical theory of gravity, general relativity
- Approaching the quantum gravity theory by the investigation of the possible extension from general relativity.
- Investigating the mathematical structures of candidates of quantum gravity theory, such as the string theory.

I am mainly working on the second topic, e.g. the property of the general relativity in higher dimension and the causal structures in extended theory from the general relativity.

Major Publications:

[1] K. Izumi, K. Koyama, O. Pujolas and T. Tanaka, "Bubbles in the Self-Accelerating Universe," Phys. Rev. D **76**, 104041 (2007)

[2] K. Izumi, "Orthogonal black di-ring solution," Prog. Theor. Phys. **119**, 757 (2008)

[3] K. Izumi, "Causal Structures in Gauss-Bonnet gravity," Phys. Rev. D **90**, no. 4, 044037 (2014)

[4] R. Emparan, K. Izumi, R. Luna, R. Suzuki and K. Tanabe, "Hydro-elastic Complementarity in Black Branes at large D," JHEP **1606**, 117 (2016)

[5] Y. Abe, T. Inami and K. Izumi, “Perturbative S-matrix unitarity ($S^\dagger S = 1$) in $R_{\mu\nu}^2$ gravity,” Mod. Phys. Lett. A **36**, no.16, 2150105 (2021)

[6] K. Izumi, Y. Tomikawa, T. Shiromizu and H. Yoshino, “Area bound for surfaces in generic gravitational field,” PTEP **2021**, no. 8, 083E02 (2021)

Education and Appointments:

2009	D. Sc., Department of Physics, Kyoto University, Japan
2009	Postdoctoral Fellow, Institute for the Physics and Mathematics of the Universe, The University of Tokyo
2011	Postdoctoral Fellow, Yukawa Institute for Theoretical Physics, Kyoto University
2011	Distinguished Junior Postdoctoral Fellow, Leung Center for Cosmology and Particle Astrophysics, National Taiwan University, Taiwan(R.O.C)
2015	Postdoctoral Fellow, Department of Physics, University of Barcelona, Spain,
2016	Assistant Professor, Department of Mathematics, Nagoya University
2021	Lecturer, Department of Mathematics, Nagoya University

Message to Prospective Students:

General relativity is constructed with a simple equation, but has the various nontrivial properties. Meanwhile, the construction of quantum gravity theory is a challenging research topic. If you want to study one of them (or both), don’t hesitate to ask me.

If you want to study these topics, it is better to start from the basics of general relativity. I recommend the following book;

- R. M. Wald, General Relativity, Chicago University Press

After mastering the basics of general relativity, you can go to the next step, reading the other books and papers that you are interested in.

KANNO, Hiroaki Professor

Office: Rm 447 in Sci. Bldg. A

Phone: +81 (0)52−789−2417 (ext. 2417)

Email: kanno@math.nagoya-u.ac.jp

Membership of Academic Societies:
JMS (The Mathematical Society of Japan),
JPS (The Physical Society of Japan)

Research Interest:

- Topological gauge/string theory and enumerative geometry
- Supersymmetric gauge theories and integrable system

Research Summary:

I am working on mathematical physics. In particular my recent interest is in topological gauge/string theory and supersymmetric gauge theories. Gauge theory, or the Yang-Mills theory is the most fundamental mathematical framework underlying the Standard Model of Elementary Particles, which is being confirmed by the recent discovery of "Higgs particle" by LHC at CERN. However, the Standard Model still has a few puzzles and does not incorporate gravity. The idea of supersymmetry is expected to resolve some of the puzzles and string theory is the most promising candidate for the unified theory including gravity.

In the study of these theories the quantum dynamics at strong coupling plays a crucial role. This is a difficult problem in general, since we cannot rely on the perturbation theory, which has been successful in the Yang-Mills theory at weak coupling. In such a circumstance exactly solvable models, even if they are toy models, are very valuable, since they will tell us some aspects of quantum dynamics beyond the perturbation theory. They are also called (quantum) integrable system. Exact solvability in quantum filed theory usually follows from infinite dimensional symmetry and/or the idea of dualities which exchanges the weak coupling and the strong coupling regions. Topological gauge/string theory is a typical example. The representation theory of infinite dimensional symmetry and the combinatorics are main mathematical tools for exact solvability. Combined with the idea of the moduli space, exactly solvable models in supersymmetic gauge/string theories sometimes "solve" hard enumerative problems in symplectic/complex geometry, for example through the mirror symmetry.

Major Publications:

[1] H. Kanno, Weil Algebra Structure and Geometrical Meaning of BRST Transformation in Topological Quantum Field Theory, *Z. Phys.* **C43** (1989) 477-484.

[2] T. Inami and H. Kanno, Lie Superalgebraic Approach to Super Toda Lattice and Generalized Super KdV Equations, *Commun. Math. Phys.* **136** (1991) 519-542.

[3] L. Baulieu, H. Kanno and I.M. Singer, Special Quantum Field Theories in Eight and Other Dimensions, *Commun. Math. Phys.* **194** (1998) 149-175.

[4] T. Eguchi and H. Kanno, Topological Strings and Nekrasov's Formulas, *JHEP* **0312** (2003) 006.

[5] H. Awata and H. Kanno, Instanton counting, Macdonald function and the moduli space of D-branes, *JHEP* **0505** (2005) 039.

Education and Appointments:

1989	JSPS post-doctoral fellow at Yukawa Institute, Kyoto
1991	Post-doctoral fellow at ICTP, Trieste
1992	Research fellow of the Nishina memorial foundation at DAMTP, Cambridge Univ.
1993	Assistant professor, Department of Mathematics, Hiroshima university
1995	Lecturer, Department of Mathematics, Hiroshima university
1998	Associate professor, Department of Mathematics, Hiroshima university
2001	Associate professor, Graduate school of Mathematics, Nagoya university
2004	Professor, Graduate school of Mathematics, Nagoya university
2010	Joint appointment at KMI (Kobayashi-Maskawa Institute), Nagoya university

Message to Prospective Students:

The recent topics of Small Group Class (the tutorial seminar) in the master course include the theory of solitons and instantons, the geometry of generalized complex structure and the quantum theory of gauge fields. Though basic knowledge of classical and quantum mechanics is preferable, it is not absolutely required. More important point is that you are full of curiosity.

The theory of integrable systems is one of the main subjects in mathematical physics. A typical method in mathematical physics is to construct the models of physical system of interest and analyze them by making a good use of mathematics. In this sense the exactly solvable models are quite remarkable both in mathematical and physical points of view. They give us valuable lessons on physical phenomena which are hard to access by approximations, while deep mathematical structures, such as symmetry and duality, underlie the integrability of the models. In the study of integrable systems the computation by hand and/or computers is also an important business.

To give you some impression on the theory of integrable systems, let me mention my favorite examples; the first one is the theory of solitons which is closely related to conformal field theory on the Riemann surface. A good reference is the following textbook:

- T. Miwa, M. Jimbo and E. Date ; translated by Miles Reid, Solitons : differential equations, symmetries and infinite dimensional algebras, Cambridge University Press , 2000.

The second example is the Seiberg-Witten theory of $\mathcal{N} = 2$ supersymmetric Yang-Mills theory in four dimensions. You may find several good review articles at "arXiv" : http://arxiv.org/. The followings are examples in early days:

- Adel Bilal, Duality in N=2 SUSY SU(2) Yang-Mills Theory, http://arxiv.org/abs/hep-th/9601007.
- L. Alvarez-Gaume and S.F. Hassan, Introduction to S-Duality in N=2 Supersymmetric Gauge Theory, http://arxiv.org/abs/hep-th/9701069.

Office: Rm 503 in Math. Bldg.
Phone: +81 (0)52−789−2410 (ext. 2410)
Email: jkato@math.nagoya-u.ac.jp
Membership of Academic Societies:
The Mathematical Society of Japan

Research Interest:

- Partial Differential Equations
- Fourier Analysis

Research Summary:

My research area is the theory of partial differential equations. I am mainly interested in nonlinear partial differential equations arising in mathematical physics, especially nonlinear dispersive equations and nonlinear wave equations. Equations in this category includes nonlinear Schrödinger equations, KdV equations, nonlinear Klein-Gordon equations, Maxwell-Schrödinger equations, etc.

I am studying such type of equations in the frame work of functional analysis. Generally, it is difficult to give a explicit solution to nonlinear partial differential equations for a given data, e.g. initial data, boundary values, we first consider the existence of a solution (and uniqueness of solutions, continuous dependence of solutions to initial data) by using functional analytic techniques. After that, we study qualitative behavior of solutions, e.g. regularity, asymptotic behavior. Fourier analysis is crucial to catch properties of solutions to dispersive equations and wave equations.

I am also interested in equations which have a geometric background, such as wave maps and the Schrödinger maps. These are considered as the generalization of the wave equation and the Schrödinger equation to the evolution of the maps between manifolds, and give interesting problems in the field of analysis and geometry, e.g. properties of the target manifold would change the global behavior of solutions.

Major Publications:

[1] J. Kato, The uniqueness of nondecaying solutions for the Navier-Stokes equations, Arch. Rational Mech. Anal. **169** (2003), 159–175.

[2] J. Kato, Existence and uniqueness of the solution to the modified Schrödinger map, Math. Res. Lett. **12** (2005), 171–186.

[3] J. Kato, M. Nakamura, T. Ozawa, A generalization of the weighted Strichartz estimates for wave equations and an application to self-similar solutions, Comm. Pure Appl. Math. **60** (2007), 164–186.

[4] J. Kato, T. Ozawa, Endpoint Strichartz estimates for the Klein-Gordon equation in two space dimensions and some applications, J. Math. Pures Appl. **95** (2011), 48–71.

Awards and Prizes:

- The MSJ Takebe Katahiro Prizes (2008)

Education and Appointments:

2003 Ph. D., Hokkaido University
2003 COE Fellow, Tohoku University
2004 JSPS Research Fellow, Kyoto University
2006 Lecturer, Nagoya University
2007 Associate Professor, Nagoya University
2009 ∼ 2011, JSPS Postdoctoral Fellow for Research Abroad, New York University

Message to Prospective Students:

For the study of dispersive equations and wave equations, basic knowledge of functional analysis and the Fourier analysis is required. So, in my small class I am planing to begin to read basic books to make students be capable of reading recent research articles. The following books are examples of the textbooks.

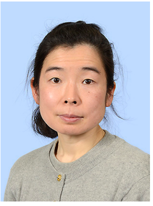
[1] H. Bahouri, J.-Y. Chemin, R. Danchin, "Fourier Analysis and Nonlinear Partial Differential Equations," Grundlehren der Mathematischen Wissenschaften **343**, Springer (2011).

[2] C. D. Sogge, "Lectures on Nonlinear Wave Equations," International Press (2008).

[3] S. Alinhac, "Hyperbolic Partial Differential Equations," Universitext, Springer (2009).

[4] L. Grafakos, "Classical Fourier Analysis," 2nd Ed., Graduate Text in Math. **249**, Springer, 2008.

[5] F. Lin, C. Wang, "The Analysis of Harmonic Maps and Their Heat Flows," World Scientific (2008).



Office: Rm 357 in Sci. Bldg. A
Phone: +81 (0)52−789−4534 (ext. 4534)
Email: tomomi@math.nagoya-u.ac.jp
Membership of Academic Societies:
The Mathematical Society of Japan

Research Interest:

- Knot theory
- Low dimensional topology

Research Summary:

Knot theory is a field of geometry and topology, where we are interested in the complexity of knots or links, i.e. simple closed curves in the space. Such complexity is expressed as numbers, polynomials, etc. We call these values by invariants of knots or links. I mainly research the between link diagrams and link invariants, for example, the number of crossing changes needed to unknot the given link. It is amazing that a lot of seemingly easy formulas are proved using advanced theories as singularity theory, contact geometry, gauge theory, or Khovanov homology theory.

The results in [1] of Major Publications are obtained from works due to Rudolph with related to 'Milnor's conjecture', solved by Kronheimer and Mrowka as researches on gauge theory. Their works relate to contact geometry and singularity theory. The articles [2, 3] are written on divide knots defined by A'Campo, a famous singularity theorist. Milnor's conjecture has been reproved combinatorially, using Khovanov homology theory established about 2000. The main result in [4] is partially reconsideration of the works in [1] after Khovanov homology theory. These results are improved in [5]. In the paper [6], as a relation to crossing changes on knots and links, we obtained a "winning method" for an advanced version of the game "Region Select" proposed in the text [9] mentioned below. We currently research how these games relate to other theories.

Recently, many researchers are interested in the relations between knot theory and the other theory: representation theory, number theory, chemistry, biology, etc. It is hard to catch up with such researches, though I am locking forward to further evolution.

Major Publications:

[1] T. Kawamura, On unknotting numbers and four-dimensional clasp numbers of links, Proc. Amer. Math. Soc. **130** (2002), no. 1, 243–252.

[2] T. Kawamura, Quasipositivity of links of divides and free divides, Topology Appl. **125** (2002), no. 1, 111–123.

[3] T. Kawamura, Links associated with generic immersions of graphs, Algebr. Geom. Topol. **4** (2004), 571–594.

[4] T. Kawamura, The Rasmussen invariants and the sharper slice-Bennequin inequality on knots, Topology **46** (2007), no. 1, 29–38.

[5] T. Kawamura, An estimate of the Rasmussen invariant for links and the determination for certain links, Topology Appl. **196** (2015), 558–574.

[6] T. Kawamura, Integral region choice problem on link diagrams, Osaka J. Math. **60** (2023), 835–872.

Awards and Prizes:

- 2003, MSJ Takebe Katahiro Prize for Encouragement of Young Researchers, Research on divide knots and four-dimensional estimates of unknotting numbers

Education and Appointments:

2000 Ph.D. in Mathematical Sciences, the University of Tokyo
2000 JSPS Research Fellowship
2002 Research Associate, Aoyama Gakuin University
2007 Associate Professor, Nagoya University

Message to Prospective Students:

The students of the small group class I take charge of, usually read textbooks on knot theory and low dimensional topology. Here are examples:

[1] J. S. Birman, *Braids, links and mapping class groups*, Ann. of Math. Studies, 82, Princeton University Press, 1974.

[2] J. M. Lee, *Introduction to topological manifolds*, Springer, 2000.

[3] L. H. Kauffman, *Formal knot theory*, Dover Publications, 2006.

[4] V. V. Prasolov and A.B.Sossinsky, *Knots, links, braids and 3-manifolds*, AMS, 1997.

[5] D. Rolfsen, *Knots and links*, Corrected reprint of the 1976 original. Math. Lect. Ser., 7. Publish or Perish, Inc., Houston, TX, 1990.

[6] N. Ito, *Category theory of knot theory* (Japanese), Nippon hyoron sha, 2018

[7] T. Ohtsuki, *Knot invariants* (Japanese), Kyoritsu Shuppan, 2015.

[8] A. Kawauchi, *Knot theory* (Japanese), Kyoritsu Shuppan, 2015.

[9] A. Kawauchi, K. Kishimoto, A. Shimizu, *Knot theory and game : Mathematical world viewing from the game "Region Select"* (Japanese) , Asakura Publishing, 2013.

[10] A. Hattori, *Topology* (Japanese), Iwanami Shoten, 1991.

They use not only main textbooks but also research papers and other books. They are expected to decide the theme of master's thesis by themselves, and read many articles where some errors or omissions exist occasionally. If you would like to start the study of knot theory quickly, I recommend you to learn fundamental group and homology from textbooks on beginning of topology in advance. I will also support your careful study on these.

I believe that you, a graduate student of Nagoya University, can manage to solve difficult problems and be glad to go a step further.

Office: Rm 331 in Sci. Bldg. A
Phone: +81 (0) 52–789–5612 (ext. 5612)
Email: kita at math.nagoya-u.ac.jp
Web-site: https://sites.google.com/view/nanaokita

Research Interest:

- Graph Theory
- Discrete Optimization (Combinatorial Optimization)
- Discrete Algorithm

Research Summary:

Graphs are a mathematical abstraction of network structures. They are a major object of study in discrete mathematics and theoretical computer science. Since network structures are ubiquitous, unraveling the structures of graphs and designing algorithms for various problems on graphs attract interest from many fields. There are numerous problems and questions that we need to solve. This is why developing powerful theoretical tools effective in diverse settings is crucial. Such tools will enable us to build systematic theories and thus accelerate the growth of the field. Decomposition theorems for graphs are particularly effective as this type of theoretical tool.

My research has focused on various decomposition theorems for graphs, which can serve as a foundation for studying them. In particular, I have engaged in canonical decomposition theory, including deriving new canonical decompositions and exploring their theoretical applications. Canonical decompositions comprise a series of structure theorems with a common trait, providing a uniquely determined decomposition for each graph and enabling an observation of its entire structure. Therefore, they function as powerful and versatile tools for studying graphs. Canonical decompositions were discovered around 1960 in the context of matching theory, a classical branch of graph theory and discrete optimization, and have been effectively employed since then. However, each known canonical decomposition has its deficiencies, such as being applicable only to specific classes of graphs. Consequently, canonical decomposition theory has long remained incomplete.

In my study, I have derived a new canonical decomposition that is applicable to all graphs and includes the generalizations or refinements of known canonical decompositions. (The generalized cathedral and nonbipartite Dulmage–Mendelsohn decomposition [1, 3].) Furthermore, I have applied this new canonical decomposition to obtain an improved proof of some classical theorems, such as the tight cut lemma by Edmonds et al. [2], and to characterize maximal barriers (dual optimizers of the maximum matching problem) in terms of lattices [3].

These results have further opened new opportunities for various subjects of graph studies beyond matching theory. That is, the theoretical foundations for these subjects can be innovated by providing structure theorems similar to canonical decompositions. In light of this, my current focus is particularly on parity factors (also known as T-joins) of graphs; see Kita [4] or other similar works. Although parity factor theory is a classical topic in discrete optimization, encompassing various routing problems as special cases, the theory still exhibits some immature aspects and needs a new development in its foundational part. Parity factor theory is also well known for its connection to a fundamental problem in statistical physics. Therefore, applying outcomes of my studies to statistical physics is also one of my research agendas.

Discrete optimization (combinatorial optimization) contributes to the foundation of the computational complexity theory and therefore makes up a part of the foundation of theoretical computer science. Grasping the true essence of discrete optimization problems solvable in polynomial time has been a longstanding theme in theoretical computer science. One of my long-term objectives is to approach this theme by exploring graph structures that represent polynomial time solvability in significant discrete optimization problems.

Major Publications:

[1] N. Kita, A partially ordered structure and a generalization of the canonical partition for general graphs with perfect matchings, Lecture Notes in Computer Science, vol. 7676 , 2012, pp. 85–94.

[2] N. Kita, Structure of towers and a new proof of the Tight Cut Lemma. Lecture Notes in Computer Science, Vol. 10627, 2017, pp. 225-239.

[3] N. Kita, Nonbipartite Dulmage-Mendelsohn decomposition for Berge duality. Lecture Notes in Computer Science, Vol. 10976, 2018, pp. 293–304.

[4] N. Kita, Graft Analogue of general Kotzig–Lovász decomposition, Discrete Applied Mathematics vol. 322, 2022, pp. 355–364.

Awards and Prizes:

- 2012, Best student paper award, 23rd International Symposium on Algorithm and Computation

Education and Appointments:

2014	Postdoctoral Research Fellow, Graduate School of Frontier Science, University of Tokyo
2015	Research Fellow of the Japan Society of the Promotion of Science (PD), National Institute of Informatics
2018	Assistant Professor, Faculty of Science and Technology, Tokyo University of Science
2022	Specially Appointed Assistant Professor, Graduate School of Information Science, Tohoku University
2023	Associate Professor, Graduate School of Mathematical Science, Nagoya University

Message to Prospective Students:

Students with a strong interest in discrete mathematics and theoretical computer science are especially welcome. For an idea of the textbooks typically used in our seminar, please refer to the following books.

[1] W. Cook, et al., “Combinatorial optimization”, Wiley, 1997.

[2] A. Bondy, and U. S. R. Murty, “Graph theory”, Springer, 2008.

[3] B. Mohar, and C. Thomassen, “Graphs on surfaces”, Johns Hopkins University Press, 2001.

[4] M. Gröschel, et al., “Geometric algorithms and combinatorial optimization”, Springer, 2012.

LE GALL, François Professor

Office: Rm 404 in Math. Bldg.

Phone: +81 (0) 52−789−2412 (ext. 2412)

Email: legall@math.nagoya-u.ac.jp

Web-site: http://www.francoislegall.com/
https://www.math.nagoya-u.ac.jp/~legall/index.html (Group)

Membership of Academic Societies:
Information Processing Society of Japan, The Mathematical Society of Japan, Association for Computing Machinery

Research Interest:

- Algorithms
- Computational complexity
- Quantum computing

Research Summary:

My research area is *theoretical computer science*, the field of study that investigates computation from a mathematical perspective. Our group works mainly on *quantum computing*, and more precisely *quantum algorithms* and *quantum complexity*. I give below a short description of these two topics. Please have a look at the web page of our group (see 2nd URL above) for more details.

Quantum algorithms. While Shor's algorithm for integer factoring and Grover's algorithm for search are the most celebrated quantum algorithms, many other quantum algorithms have been discovered in the past 25 years. One of the main goals of our group is to find novel quantum algorithms and discover "killer applications" of quantum computers. We also aim at showing the superiority of quantum algorithms via rigorous mathematical analysis of their performance. Recently we have been working on quantum algorithms for string problems [1], quantum algorithms for chemistry and other problems from physics [2] and quantum distributed algorithms [3, 5].

Quantum complexity. The central question in quantum complexity theory is to understand in which situations quantum computation is more powerful than classical computation, and then quantify the quantum advantage. In our group we investigate this question using mathematical tools, in several setting such as time complexity, space complexity, query complexity, communication complexity or complexity classes. Recently we have been working for instance on establishing quantum advantage for shallow quantum circuits [4] and making progress on the quantum PCP conjecture [2].

Major Publications:

[1] F. Le Gall and S. Seddighin. Quantum Meets Fine-grained Complexity: Sublinear Time Quantum Algorithms for String Problems. *Algorithmica*, Vol. 85(5), pp. 1251-1286, 2023.

[2] S. Gharibian and F. Le Gall. Dequantizing the Quantum Singular Value Transformation: Hardness and Applications to Quantum Chemistry and the Quantum PCP Conjecture. *Proceedings of the 54th ACM Symposium on Theory of Computing*, 19-32, 2022.

[3] K. Censor-Hillel, O. Fischer, F. Le Gall, D. Leitersdorf and R. Oshman. Quantum Distributed Algorithms for Detection of Cliques. *Proceedings of the 13th Innovations in Theoretical Computer Science conference (ITCS 2022)*, pp. 35:1-35:25, 2022.

[4] F. Le Gall. Average-Case Quantum Advantage with Shallow Circuits. *Proceedings of the 34th Computational Complexity Conference*, 21:1-21:20, 2019.

[5] F. Le Gall and F. Magniez. Sublinear-Time Quantum Computation of the Diameter in CONGEST Networks. *Proceedings of the 37th ACM Symposium on Principles of Distributed Computing (PODC 2018)*, pp. 337-346, 2018.

[6] H. Kobayashi, F. Le Gall and H. Nishimura. Stronger Methods of Making Quantum Interactive Proofs Perfectly Complete. *SIAM Journal on Computing*, Vol. 44(2), pp. 243-289, 2015.

[7] F. Le Gall: Powers of Tensors and Fast Matrix Multiplication. *Proceedings of the 39th International Symposium on Symbolic and Algebraic Computation*, pp. 296-303, 2014.

[8] F. Le Gall: Improved Quantum Algorithm for Triangle Finding via Combinatorial Arguments. *Proceedings of the 55th Annual IEEE Symposium on Foundations of Computer Science*, pp. 216-225, 2014.

Awards and Prizes:

- NISTEP Award (2017)
- ISSAC 2014 Distinguished Paper Award (2014)

Education and Appointments:

2006	PhD, Graduate School of Information Science and Technology, The University of Tokyo
2006	Researcher, ERATO-SORST Quantum Computation and Information Project, Japan Science and Technology Agency
2009	Project Lecturer, Graduate School of Information Science and Technology, The University of Tokyo
2012	Project Associate Professor, Graduate School of Information Science and Technology, The University of Tokyo
2016	Program-Specific Associate Professor, Graduate School of Informatics, Kyoto University
2019	Associate Professor, Graduate School of Mathematics, Nagoya University
2022	Professor, Graduate School of Mathematics, Nagoya University

Message to Prospective Students:

- My seminar for graduate research mainly focuses on quantum computation and quantum information, but other topics in theoretical computer science (for instance, algorithms or complexity theory) are also possible. Students can basically choose any topic related to those subjects.
- The first months of research are devoted to studying textbooks. The choice of the textbook depends on the subject and the students' background. The following textbook is often selected.

  [1] M. Nielsen and I. Chuang. *Quantum Computation and Quantum Information.* Cambridge University Press, 2010.

- Students then start reading technical research papers and getting familiar with recent research. After choosing an appropriate open problem (by discussing with me), they are encouraged to conduct original research.

Office: Rm 347 in Sci. Bldg. A
Phone: +81 (0) 52−789−5578 (ext. 5578)
Email: minami@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~minami/
Membership of Academic Societies:
Physical Society of Japan

Research Interest:

- Statistical Mechanics
- Mathematical Physics

Research Summary:

Statistical mechanics concerns basic raws which become valid in the limit of infinite degrees of freedom. It has been investigated in connection with many-body systems and condensed matter problems. Statistical mechanics is the theoretical bases to investigate various physical phenomena with large degrees of freedom, i.e. the bases of statistical physics. Statistical mechanics for non-equilibrium systems does not yet fully formulated except for the cases which lie in the neighborhood of equilibrium. It becomes difficult to investigate but becomes much more rich when interactions in the systems are assumed to be quantum mechanical.

Statistical mechanics is basically an area in traditional physics, but can also be viewed as a representation of some mathematical structure. Statistical mechanics is a subject for mathematical physics, when one concentrate especially on its mathematical structures.

Statistical mechanics relate pure mathematics through integrable systems especially solvable lattice models, e.g. Onsager's exact solution for the two-dimensional Ising model, some of the quantum spin models and vertex models. Quantum group was introduced in connection with the Yang-Baxter equation which is a key concept in this area.

Statistical mechanics has not yet been fully applied for systems with quite large but finite degrees of freedom, and still cannot explain non-equilibrium phenomena. However, in these areas, one can find interesting examples such as social and ecological phenomena, pattern formulations in network systems etc. In addition to it, quantum mechanics itself are now again investigated from the viewpoint of the new information theory that is based on purely quantum mechanical effects.

I will concern these new aspects of the statistical and quantum mechanics, in addition to the problems which I have been investigated, i.e. the problems of phase transitions in two-dimensional lattice models, exact solutions for classical and quantum lattice models.

Major Publications:

[1] K. Minami and M. Suzuki, Non-universal critical behaviour of two-dimensional Ising systems, J. Phys. **A27** (1994) 7301-7311.

[2] K. Minami, The zero-field susceptibility of the transverse Ising chain with arbitrary spin , J. Phys. **A29** (1996) 6395-6405.

[3] K. Minami, The susceptibility in arbitrary directions and the specific heat of general Ising-type chains with uniform, periodic and random structures, J.Phys.Soc.Jpn. **67** (1998) 2255-2269.

[4] K. Minami, An equivalence relation of boundary/initial conditions and the infinite limit properties, J.Phys.Soc.Jpn. **74** (2005) 1640.

[5] K. Minami, The free energies of six-vertex models and the n-equivalence relation, J. Math. Phys. **49** (2008) 033514.

Education and Appointments:

1993 Ph D, School of Science, the University of Tokyo
1995 Assistant Professor, Graduate School of Mathematics, Nagoya University
1998 Associate Professor, Graduate School of Mathematics, Nagoya University

Message to Prospective Students:

Let me list the textbooks which I have used in my seminar. It is recommended to move to original topics after finishing reading your textbooks of the statistical mechanics and the quantum mechanics.

D. N. Zubarev, " Non-equilibrium Statistical Thermodynamics"
L. D. Landau and E. F. Lifshitz, "Quantum Mechanics", "Statistical Physics"
J. von Neumann, "Mathematical Foundations of Quantum Mechanics"
A. Einstein, "Selected Papers of Professor A. Einstein"
A. S. Kompaneyets ,"Quantum Mechanics"
A. Arai and H. Ezawa, "Mathematical Structures of Quantum Mechanics"
M. A. Nielsen and I. L. Chuang, "Quantum computation and quantum information"
N. Masuda and N. Konno, "Complex Networks"
R. Kubo, "Statistical Mechanics"
Y. Higuchi, "Percolation"

Office: Rm 504 in Math. Bldg.
Phone: +81 (0)52–789–4746 (ext. 4746)
Email: moriyosi@math.nagoya-u.ac.jp
Membership of Academic Societies:
MSJ (Mathematical Society of Japan)

Research Interest:

- Differential Topology, Differential Geometry, Global Analysis
- Noncommutative Geometry
- The Atiyah-Singer Index Theorem

Research Summary:

My research interest is in the study of differentiable manifolds, in particular a generalization of the Atiyah-Singer index theorem [Ann. of Math. 87 (1968)], which reveals a profound relationship between topological and analytic invariants on differentiable manifolds. Nowadays, it is considered as one of the most beautiful and invaluable theorems in Mathematics. For instance, one of the astonishing consequences of the Atiyah-Singer index theorem is that the L and $\widehat{A}$-genera must be integers, which is a priori just rational numbers by definition. Milnor exploited the integrality theorem of L-genus to prove the existence of exotic spheres (manifolds that are homeomorphic but not diffeomorphic to standard spheres). In recent years one exploits the index theorem in an elaborated way so that many remarkable results are obtained in Low-dimensional Topology. Now the index theorem is accepted as one of the central issues in modern Mathematics.

In the 80's A. Connes, who was awarded the Fields medal in 1990, proposed a new framework in Mathematics called *Noncommutative Geometry* (NCG) [6]. Obviously the Atiyah-Singer index theorem was a strong motivation for him to establish NCG. He also introduced new methods into NCG like K-theory and cyclic cohomology and extended the Atiyah-Singer index theorem on foliated manifolds, spaces with ergodic actions, noncompact homogeneous spaces and so on. Such an index theorem can be developed on the Kronecker foliation in 2-dimension, which appears in the next page (taken from Connes' book [6]).

The influence of NCG is broad and profound in many areas of Mathematics. Thus students will be required considerable knowledge on various subjects. However, the broader you are required, the deeper you understand. I am sure that you will be more attracted to Mathematics by studying the index theorem.

Major Publications:

[1] H. Moriyoshi and T. Natsume, The Godbillon-Vey cyclic cocycle and longitudinal Dirac operators, Pacific J. Math., **172** (1996), no. 2, 483–539.

[2] H. Moriyoshi and P, Piazza, Eta cocycles, relative pairings and the Godbillon-Vey index theorem, Geom. Funct. Anal., **22** (2012), 1708–1813

[3] H. Moriyoshi and T. Natsume, *Operator algebras and geometry*, Translations of Mathematical Monographs **237**, AMS, 2008.

Education and Appointments:

1986 M.S., Univ. of Tokyo, Japan
1990 Ph.D., Pennsylvania State Univ., USA
1990 Visiting Lecturer, SUNY at Buffalo, USA
1991 Research Associate, Tokyo Institute of Technology, Japan
1995 Associate Professor, Hokkaido University, Japan
1998 Associate Professor, Keio University, Japan
2009 Professor, Nagoya University, Japan

Message to Prospective Students:

Students in the Graduate Program for Master's degree should attend Seminar (small group class). The following is a list of topics we dealt with in recent years:

- Characteristic classed of vector bundles
- de Rham cohomology and the Chern-Weil theory
- Topological K-theory
- Foliated manifolds and secondary characteristic classes
- The Atiyah-Singer index theorem

The former three are subjects related to cohomology and characteristic classes, which lay the foundation of Topology and Geometry. The latter are elaborated ones comparing to the former. Suitable references are listed in the following. P. Shanahan [4] and Roe [5] are recommended to study the Atiyah-Singer index theorem.

[1] J. Milnor, Characteristic classes, Princeton University Press,
[2] R. Bott and L. Tu, Differential Forms in Algebraic Topology, GTM 82, Springer-Verlag,
[3] J. Dupont, Curvature and characteristic classes, LNM, Vol. 640, Springer-Verlag.
[4] P. Shanahan, The Atiyah-Singer Index Theorem, LNM, Vol. 638, Springer-Verlag.
[5] J. Roe, Elliptic operators, topology and asymptotic methods, Longman.
[6] A. Connes, Noncommutative Geometry, Academic, 1994.

Prerequisites for attending Seminar (small group class) are subjects of level 1; see our web cite. They include Calculus, Linear Algebra, Complex analysis. Students are also expected to have backgrounds on Differentiable manifolds, Differential Geometry and Homology and Homotopy theory. However, what is most important is enthusiasm for Mathematics. I am looking forward to meeting such students who want to study every subject they got interested in. It is just like Terentius, a Roman playwright, *Humani nil a me alienum puto.*

In Ph.D. course, students will be supervised who are interested in Differential Topology, Differential Geometry and Global Analysis.

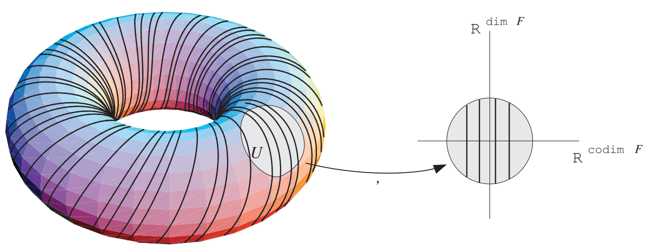


FIGURE 6. Foliation

A. Connes, *Noncommutative Geometry*, Academic Press.

Office: Rm 508 in Math. Bldg.
Phone: +81 (0) 52−789−5392 (ext. 5392)
Email: nagao@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~nagao/nagaoeng.html
Membership of Academic Societies:
The Physical Society of Japan

Research Interest:

- Random matrix theory and its applications
- Semiclassical quantum theory

Research Summary:

I study random matrices from the viewpoints of fundamental theory and various applications. The theory of random matrices (matrices with random number elements) originated in the field of mathematical statistics at the beginning of the twentieth century. Since Wigner introduced random matrices to the research of nuclear physics, the range of their applications has been expanded to many areas, including analytic number theory, combinatorics, elementary particle physics, solid state physics, statistical mechanics and ecology. In particular, the developments in the last two decades can be described as explosive and new discoveries have been reported one after another.

One of the most important problems in random matrix theory is the universality of energy level statistics. It is known that the energy levels of quantum systems are distributed according to universal laws depending on the underlying classical dynamics. If the underlying classical dynamics is chaotic, universal level correlations are observed in agreement with the prediction of random matrix theory. I have investigated the relation between random matrices and semiclassical quantum theory in order to clarify the cause of the universality.

Random matrices can also be applied to the network theory as mathematical models describing the connection pattern of networks. The network theory is a focus of current interest due to the popularization of mobile phones and internet. I wish to contribute to the study of such realistic problems, and as well to obtain inspirations from them to deepen the understanding of the fundamental theory.

Major Publications:

[1] T. Nagao, Correlation functions for multi-matrix models and quaternion determinants, Nucl. Phys. **B602** (2001) 622-637.
[2] T. Nagao, Dynamical correlations for vicious random walk with a wall, Nucl. Phys. **B658** (2003) 373-396.
[3] T. Nagao and T. Sasamoto, Asymmetric simple exclusion process and modified random matrix ensembles, Nucl. Phys. **B699** (2004) 487-502.
[4] T. Nagao, P. Braun, S. Müller, K. Saito, S. Heusler and F. Haake, Semiclassical theory for parametric correlation of energy levels, J. Phys. A: Math. Theor. **40** (2007) 47-63.
[5] P.J. Forrester and T. Nagao, Eigenvalue statistics of the real Ginibre ensemble, Phys. Rev. Lett. **99** (2007) 050603.

[6] T. Nagao and G.J. Rodgers, Spectral density of complex networks with a finite mean degree, J. Phys. A: Math. Theor. **41** (2008) 265002.

[7] G. Akemann and T. Nagao, Random matrix theory for the Hermitian Wilson Dirac operator and the chGUE-GUE transition, J. High Energy Phys. 2011 (2011) 60.

[8] G.J. Rodgers and T. Nagao, Complex Networks, The Oxford Handbook of Random Matrix Theory (ed. by G. Akemann, J. Baik and P.Di Francesco, 2011) Chapter 43.

Awards and Prizes:

- Ryogo Kubo Memorial Prize (2011) "Random matrix theory and its applications to physics"

Education and Appointments:

1994	Doctor (Science), University of Tokyo
1994	Assistant Professor, Osaka University
2004	Associate Professor, Nagoya University
2009	Professor, Nagoya University

Message to Prospective Students:

Possible themes in the master course can be listed as, for example, probability theory, statistical mechanics, chaotic dynamical systems and network theory. These themes are universal and fundamental subjects in mathematical sciences, and deeply related to the theory of random matrices. It is also possible to treat other themes, depending on the wish of the participants.

In the doctor course, I recommend students to take part in the research of novel areas, in which the number of researchers is still relatively small, and to create their own styles of research. I also like to encourage them to find influential and solvable problems by keeping eyes on the newest developments.

Office: Rm 408 in Math. Bldg.
Phone: +81 (0) 52−789−2415 (ext. 2415)
Email: naito@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~naito/

Membership of Academic Societies:
MSJ (Mathematical Society of Japan)

Research Interest:

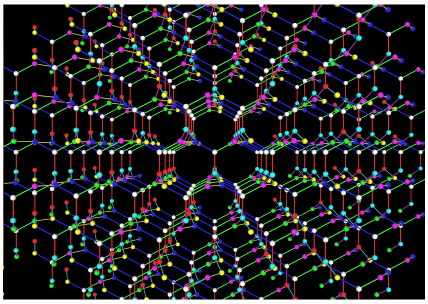
- Geometric Variational Problems
- Nonlinear Partial Differential Equations
- Discrete Geometric Analysis

Research Summary:

I am interested in "Geometric Variational Problems". In particular, I study "Nonlinear Differential Equations with respect to Geometric Variational Problems" and "Discrete Geometric Analysis".

Geometric Variational Problems are geometric objects defined by variational principles. For example, "Harmonic Maps" and "Minimal Surfaces" are well-known geometric objects defined by variational principles, and they are defined by non-linear differential equations. I my research, I study differential equations of above types by using their geometric properties (cf. [3]).

On the other hand, from mathematical view points. "Crystal Lattice" in Material Sciences is defined by graphs with symmetries, and they are also defined by variational principles. I also study Crystal Lattices by using geometric view points (cf. [1, 2]).



Major Publications:

[1] M. Itoh, M. Kotani, H. Naito, T. Sunada, Y. Kawazoe, T. Adschiri, New metallic carbon crystal, Physical Review Letters, **102**, (2009) 055703.

[2] H. Naito, Visualzation of standard realized crystal lattices, Comptenporary Mathematics, **484**, (2009) 153–164.

[3] H. Naito, Finite time blowing-up for the Yang-Mills gradient flow in higher dimension, Hokkaido Math. J., **23** (1994), 451–464.

Education and Appointments:

1988 Assistant Professor, Nagoya University
1995 Associate Professor, Nagoya University

Message to Prospective Students:

Main subject of my classroom is “mathematics by computer approach”. Examples of subjects are “Numerical analysis of differential equations”, “Computer approach for discrete geometric analysis”. In my classroom, I recommend that students does not study only methematical theory of a subject, but should also study computational experiments them.

For that reason, I require that stundents have studied basic mathematics (eg. calculas, linear algebra), and have skill of standard programmings.

Office: Rm 406 in Math. Bldg.
Phone: +81 (0) 52−789−5575 (ext. 5575)
Email: nakanisi@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~nakanisi/
Membership of Academic Societies:
Japanese Mathematical Society

Research Interest:

- integrable systems
- cluster algebras
- quantum groups

Research Summary:

Since the late 80's I have been working on the mathematical methods and aspects of the integrable quantum systems, such as conformal field theories, S-matrix models, and quantum spin chains. Until 2008, my method was mainly based on the affine Lie algebras and their quantizations (quantum groups). In that method we found various interesting interrelations between integrable systems and representation theory of Lie algebras and quantum groups. To name few key words, the level-rank duality, the Kirillov-Resehtikhin modules, the dilogarithm identities, Q-, T- and Y-systems, q-characters, fermionic formulas, and so on. Many problems were solved (by myself and other researchers) as a result of the development of the representation theory of quantum groups in these twenty years, but some problems were left almost untouched.

Since 2008, I drastically changed the strategy, and started to study these problems from the point of view of *cluster algebras*. The cluster algebras are a new class of commutative algebras introduced by Sergey Fomin and Andrei Zelevinsky around 2000. (So, it is one of mathematics in *this* century!.) The original motivation of the introduction of cluster algebras was to study the structure of the coordinate ring of some algebraic varieties. However, it turns out that a cluster algebra is a key concept to understand some of the unsolved problems mentioned above, and, amazingly and unexpectedly, some of the seemingly untouchable problems were suddenly solved with this new method.

Here I list some of the main results which I obtained with several collaborates. See the next section for the list of references.

- The dilogarithm identities for the quantum affine algebras of simply laced type [1].
- The periodicity of Y-systems and the associated dilogarithm identities for the quantum affine algebras of nonsimply laced type [2].
- The tropicalization method in cluster algebras [2].
- The dilogarithm identities associated with any period of a cluster algebra [3].
- The duality of the c-vectors and the g-vectors [3].
- The relation between the classical and quantum dilogarithm identities [4].
- The determination of the c-vectors and d-vectors of the cluster algebras of finite type [5].
- The periodicity of the sine-Gordon Y-systems and the associated dilogarithm identities [6].

Major Publications:

(Only after 2008. See http://www.math.nagoya-u.ac.jp/ nakanisi/research/publications.html for the compete list)

[1] T. Nakanishi, Dilogarithm identities for conformal field theories and cluster algebras: simply laced case, Nagoya Math. J. **202** (2011) 23–43.

[2] R. Inoue, O. Iyama, B. Keller, A. Kuniba, T. Nakanishi, Periodicities of T and Y-systems, dilogarithm identities, and cluster algebras I: Type B_r, arXiv:1101.1880, to appear in Publ. RIMS.

[3] T. Nakanishi, Periodicities in cluster algebras and dilogarithm identities, in Representations of algebras and related topics (A. Skowronski and K. Yamagata, eds.), EMS Series of Congress Reports, European Mathematical Society, 2011, pp.407-444.

[4] R. M. Kashaev, T. Nakanishi, Classical and Quantum Dilogarithm Identities, SIGMA **7** (2011), 102, 29 pages.

[5] T. Nakanishi, S. Stella, Diagrammatic description of c-vectors and d-vectors of cluster algebras of finite type, arXiv:1210.6299.

[6] T. Nakanishi, S. Stella, Wonder of sine-Gordon Y-systems, arXiv:1212.6853.

Education and Appointments:

1985-1990	Graduate School of Science, Tokyo University (Doctor in Science, 1990)
1990–1994	Assistant Professor, Nagoya University
1992–1994	JSPS Fellow for Research Abroad, Harvard University
1994–	Associate Professor, Nagoya Univerisy
2012	Research Member, MSRI, Berkeley

Message to Prospective Students:

You do not have to follow my research interest. On the contrary, it is important to find your research interest for yourself, because in most cases the research in the graduate school will influence decisively the lifetime direction of your research.

Office: Rm 345 in Sci. Bldg. A
Phone: +81 (0)52−789−2545 (ext. 2545)
Email: nakaoka.hiroyuki@math.nagoya-u.ac.jp

Membership of Academic Societies:
MSJ (The Mathematical Society of Japan)

Research Interest:

- homological algebra
- representation theory of algebras
- category theory

Research Summary:

By virtue of the abstraction, category theory is suitable for providing general theory applicable to a wide range of areas. My research aims to capture categorical frameworks appearing in algebra. Especially in recent years I have been interested mainly in categories and functors used in the representation theory of algebras. The representation theory of algebras involves categories in various ways, including major class of categories for homology algebra such as abelian categories, exact categories, triangulated categories, and more advanced ones. Recently I am engaged in research on the structure of categories and functors related to this area.

Major Publications:

[1] H. Nakaoka and Y. Palu, Extriangulated categories, Hovey twin cotorsion pairs and model structures, Cah. Topol. Géom. Différ. Catég. **60** (2019) no. 2, 117–193.
[2] H. Nakaoka, A simultaneous generalization of mutation and recollement on a triangulated category, Appl. Categ. Structures, **26** (2018) no. 3, 491–544.
[3] H. Nakaoka, General heart construction on a triangulated category (I): unifying t-structures and cluster tilting subcategories, Appl. Categ. Structures, **19** (2011) no.6, 879–899.

Awards and Prizes:

- MSJ Takebe Katahiro Prize for Encouragement of Young Researchers (2010)

Education and Appointments:

2009 Ph.D. at The University of Tokyo
2009 Project Researcher, The University of Tokyo
2009 Project Research Associate, The University of Tokyo
2010 Associate Professor, Kagoshima University
2019 Associate Professor, Nagoya University

Message to Prospective Students:

Envisaged theme for the seminar is category theory appearing in the representation theory of algebras. Mainly supposed are category theory related to homological algebra in abelian categories and triangulated categories. I hope you to have a home ground (a research area dealing with concrete objects) which will become a source of your research, rather than entirely focused on abstract category theory, so I recommend to the learn representation theory of algebras. The following is a candidate of textbook in this direction.

- I. Assem; D. Simson; A. Skowroński, *Elements of the representation theory of associative algebras. Vol. 1. Techniques of representation theory.* London Mathematical Society Student Texts, **65**. Cambridge University Press, 2006.

Basic knowledge of linear algebra, group theory and ring theory are desirable prior to entering the master course. In particular, it is necessary to have knowledge of modules over rings dealt in the undergraduate course. Besides, it is desirable to have some familiarity with homological algebra in abelian categories or like that.

NAKASHIMA, Makoto — Associate Professor

Office: Rm 453 in Sci. Bldg. A
Phone: +81 (0)52−789−2421 (ext. 2421)
Email: nakamako@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~nakamako/
Membership of Academic Societies:
MSJ (The Mathematical Society of Japan)

Research Interest:

- Probability
- Large scale interacting systems

Research Summary:

Probability theory means "measure theoretic probability theory" which is completely different from combinatorial probability and statistics. Lectures in measure theory are usually given to junior students majoring in mathematics. In measure theory, we define "areas" of measurable sets in a set S and then we can construct Lebesgue integral of a measurable function. In measure theoretical probability, measurable sets in sample space Ω is called events and their "areas" are identified as probabilities. Measure theoretic probability allows us to consider "infinitely many trials" mathematically and analyze them.

The large scale interacting systems are closely related to physics. We shall explain it through polymers which is one of my research interests.

Polymers are large molecules created via polymerization of small molecules, *monomers*, e.g. $(-CH_2-)$. Each bond between −C−s has a freedom of rotation, i.e. is random. We will simplify the models by ignoring exclusivity between monomers. We consider a polymer chain with length $n+1$ and we set the position of one endpoint (monomer 0) of chain as 0 and denote by S_i the position of ith-monomers. Moreover, we assume that the displacements $\{X_i := S_i - S_{i-1}\}_{i=1}^n$ are independent and identically distributed. Then, this is a random walk that is well-studied. Now, we study the shape of polymer chains. Investigating polymers macroscopically can be regarded as the scaling limit of random walk. When $\{X_i\}_{i=0}^n$ satisfies a proper assumption, the scaling limit of $\{S_i\}_{i=0}^n$ is the Brownian motion (**invariance principle**). Thus, the shape of polymers in an ideal medium can be regarded as the trace of Brownian motion.

How about the case for the polymers in a medium with impurities? We may believe that there exists some interaction between impurities and monomers. This interaction is described via a new probability measure called Gibbs measure. This measure is generated by assigning a weight representing an interaction to each path $\{S_i\}_{i=0}^n$. Changing a parameter (e.g. concentration of impurities), the shape of polymers under Gibbs measure is changed completely(**phase transition**). Thus, interaction between impurities and monomers (large scale interaction) yields a new phenomenon.

There are other physical models classified as large scale interacting systems and many branches.

Usually, the phase transition is characterized in terms of the quantity "free energy". Recently, I have studied the asymptotics of the free energy and found the universality structure behind the physical models.

Major Publications:

[1] C. Cosco, S. Nakajima, M. Nakashima: Law of large numbers and fluctuations in the sub-critical and L^2 regions for SHE and KPZ equation in dimension $d \geq 3$. Stochastic Process. Appl. **151** (2022), 127–173.

[2] M. Nakashima: Free energy of directed polymers in random environment in 1+1-dimension at high temperature. Electron. J. Probab. **24** (2019), No. 50.

[3] M. Nakashima: Branching random walks in random environment and super-Brownian motion in random environment. Ann. Inst. Henri Poincaré Probab. Stat. **51** (2015), no. 4, 1251–1289.

Awards and Prizes:

- 2014, MSJ Takebe Katahiro Prize for Encouragement of Young Researchers「Study of branching random walks in random environment」

Education and Appointments:

2012 Assistant Professor, University of Tsukuba
2015 Associate Professor, Nagoya University

Message to Prospective Students:

When you learn measure theoretic probability, calculus and linear algebra are needed. Moreover, it is better to master the measure theory. Before entering graduate school, you have to learn the measure theoretic probability (σ-algebra, independence, law of large numbers, central limit theorem, conditional expectation). The following is a standard textbook of measure theoretic probability.

[1] Williams「Probability with martingales」Cambridge Mathematical Textbooks, 1991.

Office: Rm 429 in Sci. Bldg. A
Phone: +81 (0) 52−789−2814 (ext. 2814)
Email: nayatani@math.nagoya-u.ac.jp
Web-site:
Membership of Academic Societies:
Mathematical Society of Japan

Research Interest:

- Rigidity of discrete groups
- Conformal geometry

Research Summary:

My subject of study is geometry. I learned differential geometry when I was a student, and since then I have studied topics in differential geometry and those related to geometry. In past, I studied the instability index of minimal surfaces, scalar curvature equations, geometric structures associated with real and complex Kleinian groups, self-dual metrics, CR geometry and quaternionic CR geometry. The key words for them will be surface geometry, geometric analysis and conformal geometry.

My recent research is on the actions of discrete groups (that is, infinite countable groups) on spaces. It is supposed that the spaces have metrics and the actions preserve them. The prototype of such situation is the action of the fundamental group of a Riemannian manifold on its universal covering space. In such a case, the action is good in the sense that it is properly discontinuous. We consider actions of more general discrete groups on more general metric spaces, but the metric spaces are not completely arbitrary; they will be assumed to be similar to Riemannian manifolds of nonpositive sectinal curvature. In this setting, according to the choices of discrete groups and metric spaces, it can happen that good actions are extremely rare or never exist. Such discrete groups are known to have very special algebraic property, but it has not been understood very well whether such groups (in particular, having also the property of so-called hyperbolicity) exist in abundance.

We could prove that such groups do exist in abundance by using methods with origin in differential geometry and geometric analysis (in particular, maps minimizing certain energy) and combining them with the theory of random groups. An interesting future problem is to construct such groups explicitly, instead of appealing to the random group theory.

The original motivation for this research was the following problem: Prove geometrically the Margulis superrigidity theorem, a rigidity theorem for lattices of certain algebraic groups, when the algebraic groups are the matrix groups with coefficients in p-adic numbers. The Margulis theorem can be formulated in the above setting, but a geometric proof is not yet completed. I'm working on this problem again, though I abandoned it for some time.

Major Publications:

[1] H. Izeki and S. Nayatani, Combinatorial harmonic maps and discrete-group actions on Hadamard spaces, Geom. Dedicata **114** (2005), 147–188.

[2] S. Nayatani, Patterson-Sullivan measure and conformally flat metrics, Math. Z. **225** (1997), no. 1, 115–131.

Awards and Prizes:

- 2004, Geometry Prize.

Education and Appointments:

1990	JSPS Post-doctoral Fellow, Osaka University
1991	Research Associate, Tohoku University
1994	Associate Professor, Tohoku University
1998	Associate Professor, Nagoya University
2005	Professor, Nagoya University

Message to Prospective Students:

The themes of my seminar for master course students have been Riemannian goemetry and geometric analysis, geometry and analysis of groups, hyperbolic geometry, and so one. For details, please look at the past course designs (in Japanese) available at

`http://www.math.nagoya-u.ac.jp/ja/education/archive/`

In each year I propose a theme of the seminar, but the details are decided by discussing with the students. (They depend on the students' preliminary knowledge, interest and the future career.) The provisional purpose of the seminar will be to master the assigned theme through working with it for one or two years. The students, however, may shift to other topics in geometry if they get interested in them in the course of their study, as I consider it desireable to find the object of your interest by yourself.

OHIRA, Toru Professor

Office: Rm 341 in Sci. Bldg. A

Phone: +81 (0)52−789−2824 (ext. 2824)

Email: ohira@math.nagoya-u.ac.jp

Membership of Academic Societies:
Physical Society of Japan,
Japanese Society for Mathematical Biology

Research Interest:

- Mathematical Biology and Physiology
- Delayed Stochastic Systems
- Chases and Escapes

Research Summary:

Many natural and artificial systems are associated with noise and feedback or interaction " delay ". Examples includes stochastic differential equations with delay, bio-physiological controls, neural networks, traffic flows, electrical circuits, and so on. These systems can show surprisingly rich behaviors to otherwise simple systems.

The main theme of my research has been investigating and seeking applications of such " delayed stochastic systems ". For example, I proposed the concept of "delayed random walks" as a mathematical framework for studying such systems. A delayed random walk is a random walk in which the transition probability depends on the position of the walker at a fixed time interval in the past. It has been used to model human postural controls and neural activities in comparison to experimental data. Typically, oscillatory autocorrelation function is associated with delayed random walks of sufficiently long delay. To study such oscillatory behavior in stationary and transient states, we have studied analytically tractable models. On the basis of this theory, we have also devised a method of estimating delay from noisy time series coming out of linear delayed feedback systems.

I have also proposed the concept of "delayed stochastic control". The main motivation of such a hypothesis is the fact that humans can often handle situations or objects whose time constant is much faster than their reaction time. Compared to artificial systems, humans are "very slow" with a reaction time of a few hundred mili-seconds. Of course, one cannot relay only on feedbacks, predictive controls are also important. However, the key question is whether they are enough or not. For example, by combining these traditional control schemes, can we create a robot with a reaction time of that of a human (approximately 200 mili-seconds), and which can ride a unicycle? Recent experiments, for example, a human balancing a stick on the fingertips began to pose these questions. Most of the fluctuating movement of the stick is much faster than 200 mili-seconds. Delayed stochastic control is a new scheme, which takes advantage of resonant phenomena with an appropriate amount of noise level and feedback delay time. We analyzed this delayed stochastic resonant phenomena by considering the stability of repulsive delayed random walks. We also discovered a new effect: someone can better balance the stick on the fingertips, if they move an object with the other hand in a fluctuating manner. This is likely to be a piece of supporting evidence for delayed stochastic controls.

These theoretical works on delayed stochastic systems have been used by other researchers to model or analyze their experimental results. Examples include feedback resonant phenomena of solid-state laser experiments, analysis of human eye saccade movements, and so on. As related topics, I have also worked on problems such as high-frequency currency exchange market behaviors and simple computer network traffic models. I authored a book in Japan compiling these research activities in 2006.

I have also recently proposed a new theme of "Group Chase and Escape". "Chase and Escape" or "Pursuit and Evasion" is mainly mathematical research topic with long history. Its main applications have been that of military issues. The topic has also found a connection with the game theory, developed under the name of a "differential game theory". The collective motions of self-driven particles, on the other hand, have been studied actively in recent years. They include models of school of fish, flock of birds, traffic flow, and so on. My motivation to introduce the theme of "Group Chase and Escape" is to provide a platform of research to combine above two fields. The models we proposed are simple. Yet, it showed rather unexpected and complex group behaviors. Our paper is covered in a "News and Views" section of Nature (by Tamas Vicsek, 1 July, 2010, vol. 466, pp.43-44; attached), noting its originality. At the same time, however, there are much to be done from this point on this topic.

First, we need to develop theoretical method to analyze the result of computer simulations on our models. We have observed escaping and chasing in groups with their size varying in time. These spatio-temporal patterns are yet to be understood mathematically. Effects of delay and noise are also to be studied. Secondly, I hope to extend models into various directions. An example is to consider chases and escapes in the context of traffic models such as optimal velocity models. Combination with various models of swarms and swarm intelligence will be another direction of interest.

Applications and connections to natural and artificial systems are also of importance. Actual data from animal or fish hunting and evading in groups could be of high value in this context. There are recent developments in this direction such as study of a flock of pigeons using GPS devices. How to reflect these data sets to modeling or how to suggest experimental paradigm or chasing strategies from model simulations will be an important research direction. The same story can be envisioned with a large number of small interacting robots. Also, effective virus tracking both in physical and cyber spaces would be an important issue socially.

Major Publications:

[1] T. Ohira and Y. Sato: Resonance with Noise and Delay, Physical Review Letters, **82** (1999), 2811–2815.

[2] T. Ohira and T. Yamane: Delayed Stochastic Systems, Physical Review E, **61** (2000), 1247–1257.

[3] A. Kamimura and T. Ohira: Group Chase and Escape, New Journal of Physics, **12** (2010), 053013

Education and Appointments:

1993 Ph.D. in Physics, The University of Chicago
1993 Reseacher, Sony Computer Science Laboratories
2012 Professor, Nagoya University

Message to Prospective Students:

I have worked with researchers from various fields. Though it can be challenging to step outside of mathematics, there are many phenomena which still need to be formulated in the language of mathematics. This side of mathematical endeavor is as interesting as solving difficult known mathematical problems. Some representative textbooks, which reflect my interests, are the following:

[1] B. Balachandran, T. Kalmar-Nagy and D.E. Gilsinn, Delay Differential Equations: Recent Addvances and New Directions, Springer, 2009.

[2] L. Glass and M. C. Mackey, From Clocks to Chaos: The Rhythms of Life, Princeton Univ. Press, 2007.

[3] P. J. Nahin, Chases and Escapes: The Mathematics of Pursuit and Evasion, Princeton Univ. Press, 2007

Office: Rm 351 in Sci. Bldg. A

Phone: +81 (0)52−789−2431 (ext. 2431)

Email: shuno@math.nagoya-u.ac.jp

Membership of Academic Societies:
MSJ（The Mathematical Society of Japan）

Research Interest:

- p-adic representations of a complete discrete valuation field
- p-adic differential equation

Research Summary:

I study p-adic aspects of algebraic number theory. In modern number theory, as in the proof of Fermat's last theorem due to Taylor and Wiles, it is important to study algebraic varieties and its p-adic étale cohomology V. The absolute Galois group $G_{\mathbb{Q}}$ of $\mathbb{Q}$ acts naturally on V and we study the Galois action by restricting $G_{\mathbb{Q}}$ to its decomposition groups D. The most critical case is $D = G_{\mathbb{Q}_p}$, that is, the absolute Galois group of the p-adic number field $\mathbb{Q}_p$. Fontaine established a fundamental theory of p-adic representations of $G_{\mathbb{Q}_p}$ arising in the above situation: He classified p-adic representations V by using rings of p-adic periods, then he associated linear algebraic objects (p-adic Hodge structure) to V. Berger related a p-adic Hodge structure of V to the solution space of a certain p-adic differential equation, and he proved Fontaine's p-adic monodromy conjecture. Brinon generalized Fontaine's theory where $G_{\mathbb{Q}_p}$ is replaced by the absolute Galois group of a complete discrete valuation field with imperfect residue field. In my early study ([1,2]), I proved a partial generalization of Berger's theory in Brinon's setup.

I am also studying the asymptotic behavior of solutions of p-adic differential equations. On the p-adic number field $\mathbb{Q}_p$, a naïve analogue of analytic continuation fails because of its totally discontinuity. So, when we study p-adic differential equations, beside the existence of solutions, it is important to study the asymptotic behavior of the solutions around the boundary, that is, the edge of its convergent disc. Around the 1970s, Dwork established the fundamental theory on the asymptotic behavior of solutions of p-adic differential equations. He also (vaguely) stated some basic conjectures, but there had been little progress until recently. In late 2000s, André and Chiarellotto-Tsuzuki re-considered Dwork's theory, and they obtained some important results on Dwork's conjecture. In [3], I gave a negative answer to a problem of André on the logarithmic growth Newton polygon of p-adic differential equations by constructing a certain p-adic differential equation of rank 2.

Major Publications:

[1] S. Ohkubo, The p-adic monodromy theorem in the imperfect residue field case, Algebra and Number Theory 7 (2013), No. 8, 1977–2037.

[2] S. Ohkubo, On differential modules associated to de Rham representations in the imperfect residue field case, arXiv:1307.8110.

[3] S. Ohkubo, A note on logarithmic growth Newton polygons of p-adic differential equations, to appear in International Mathematics Research Notices 2014; doi: 10.1093/imrn/rnu017.

Awards and Prizes:

- MSJ Takebe Katahiro Prize for Encouragement of Young Researchers (2014)

Education and Appointments:

2012-2015 JSPS post-doc at The University of Tokyo

Message to Prospective Students:

- Background knowledge

When I was an undergraduate student, I learned basics of algebraic number theory by reading

J.-P. Serre, "A Course in Arithmetic"

J. W. S. Cassels, A. Frohlich, "Algebraic number theory".

To study number theory, I think that it is better to have some knowledge about elliptic curves. I learned it by reading

J. H. Silverman, "The arithmetic of elliptic curves".

(A) Basic texts on Fontaine's theory on p-adic representations

1. J.-M. Fontaine, Y. Ouyang, "Theory of p-adic Galois representations"
2. O. Brinon, B. Conrad, "Notes on p-adic Hodge theory"
3. L Berger, "An introduction to the theory of p-adic representations"
4. J. Tate, "p-divisible groups"

(B) Basic texts on p-adic differential equations

5. K S. Kedlaya, "p-adic differential equations"
6. B. Dwork, "On p-Adic Differential Equations II: The p-Adic Asymptotic Behavior of Solutions of Ordinary Linear Differential Equations with Rational Function Coefficients"

Potential students who want to study Fontaine's theory on p-adic representations or p-adic differential equations under my supervision should look at [3] or § 0 of [5] respectively.

Office: Rm 325 in Sci. Bldg. A

Phone: +81 (0)52−789−2543 (ext. 2543)

Email: ohtaZmath.nagoya-u.ac.jp (Please replace Z by @)

Membership of Academic Societies:
Mathematical Society of Japan

Research Interest:

- symplectic geometry
- Floer theory
- gauge theory

Research Summary:

I am working on symplectic geometry, whose origin goes back to classical mechanics. Symplectic manifold is by definition a smooth manifold admitting a non-degenerate closed 2-form. Typical examples are cotangent bundle on which classical mechanics is described, and submanifolds in complex projective spaces.

My recent interest is Floer theory and relationship between singularities and symplectic/contact geometry. I am now working on Floer theory from the point of view of certain homotopical algebra, so called A_∞ algebra. Such a homotopical algebra is a classical object originally arising from topology but it is now making new progress, partially motivated from physics. In particular, collaborating with K. Fukaya, Y-G. Oh and K. Ono, I constructed a filtered A_∞ algebra associated to a Lagrangian submanifold of a symplectic manifold and developed Lagrangian intersection Floer theory based on the filtered A_∞ algebra. (See Reference 1-[1] below.) This A_∞ algebra plays an important and fundamental role in mirror symmetry, which claims correspondence between symplectic geometry on a symplectic manifold X and complex geometry on the mirror complex manifold $\check{X}$. As a consequence, for example, certain symplectic invariant of X defined by using solutions to some non linear partial differential equation will be surprisingly derived from certain complex geometric invariants of $\check{X}$ defined by some linear differential equation. Our theory gives not only mathematical foundation in mirror symmetry but also provides some new applications to concrete problems in symplectic geometry. (See Reference 1-[2][3], for example.)

Major Publications:

1. Floer theory and mirror symmetry:

[1] K. Fukaya, Y-G. Oh, H. Ohta and K. Ono, Lagrangian intersection Floer theory –Anomaly and Obstruction–. vol **46-1**, vol **46-2**. AMS/IP Studies in Advanced Mathematics. American Mathematical Society/International Press (2009).

[2] K. Fukaya, Y-G. Oh, H. Ohta and K. Ono, Lagrangian Floer theory on compact toric manifolds I. Duke Math. J. **151**, 23–175. (2010).

[3] K. Fukaya, Y-G. Oh, H. Ohta and K. Ono, Lagrangian Floer theory on compact toric manifolds II: Bulk deformations. Selecta Math. New Series, **17**, 609-711. (2011).

[4] K. Fukaya, Y-G Oh, H. Ohta and K. Ono, Lagrangian Floer theory and mirror symmetry on compact toric manifolds. Astérisque, **376**, Société Mathématique de France (2016).

2. Singularity and symplectic/contact geometry:

[1] H. Ohta and K. Ono, Simple singularities and topology of symplectically filling 4-manifold. Comment. Math. Helv. **74**. 575–590. (1999).

[2] H. Ohta and K. Ono, Simple singularities and symplectic fillings. J. Differential Geom. **69**, 1–42. (2005).

[3] H. Ohta and K. Ono, Examples of isolated surface singularities whose links have infinitely many symplectic fillings. J. Fixed Point Theory and Applications. **3**, (V.I. Arnold Festschrift Volume) 51–56. (2008).

3. Gauge theory:

[1] M. Furuta and H. Ohta, Differentiable structures on punctured 4-manifolds. Topology and its Appl. **51**. 291–301 (1993).

[2] H. Ohta and K. Ono, Notes on symplectic 4-manifolds with $b_2^+ = 1$, II. Internat. J. of Math. **7**. 755–770. (1996).

[3] H. Ohta, Brieskorn manifolds and metrics of positive scalar curvature. Advance Studies Pure Math. **34**. 231–236. (2002).

Message to Prospective Students:

Here are some examples of texts which I used in my seminar (for the first year of master course).

1. M. Audin, Torus actions on symplectic manifolds, 2nd revised edition, Birkhäuser (2004).
2. M. Audin and M. Damian, Morse theory and Floer homology, Springer. (2014).
3. D. McDuff and D. Salamon, Introduction to symplectic topology, Oxford Univ. Press (1995).
4. N. Hitchin, The self-dual equations on a Riemann surface, Proc. London Math. Soc **55** (1987) 59-126.
5. H. Hofer and E. Zehnder, Symplectic invariants and Hamiltonian dynamics, Birkhäuser. (1994).

It is expected to already master manifold theory, (co)homology theory, elementary differential geometry, topology but the most important is to study by yourself what you don't know. Of course, I will give some advice and suggestion, if necessary. To get an impression on the basic literature, please look at the following books:

1. K. Fukaya, Symplectic geometry, Iwanami, (1999) (in Japanese).
2. D. McDuff and D. Salamon, J-holomorphic curves and symplectic topology, American Math. Soc. (2004).
3. P. Seidel, Fukaya categoryies and Picard-Lefscetz theory, Zurich Lectures in Advanced Math., Eurp. Math. Soc. (2008).

28/Nov/2017

OKADA, Soichi — Professor

Office: Rm 427 in Sci. Bldg. A
Phone: +81 (0) 52−789−5596 (ext. 5596)
Email: okada@math.nagoya-u.ac.jp
Web-site:
Membership of Academic Societies:
Mathematical Society of Japan, American Mathematical Society

Research Interest:

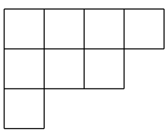
- Enumerative and Algebraic Combinatorics
- Combinatorial Representation Theory

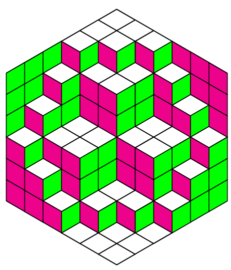
Research Summary:

My research interests are in combinatorics and its connection with algebra, representation theory, and integrable systems. I am working in the area where combinatorics meets with other fields of mathematics (and science). More specifically, I am interested in combinatorial problems arising from the representation theory of classical groups and related algebras, and also in enumeration problems of plane partitions, alternating sign matrices, and so on.

Combinatorial objects and techniques play an important role in representation theory. For example, Young diagrams (see the left figure below) are used to parameterize the irreducible representations of symmetric groups and general linear groups. Many concrete problems in representation theory (e.g., construction of irreducible representations, irreducible decomposition of a given representation) can be solved or attacked by using combinatorial methods. On the other hand, some combinatorial algorithms, e.g., the Robinson–Schensted correspondence, are now interpreted in terms of the crystal basis for quantum groups from the view point of representation theory. With these interactions between combinatorics and representation theory in mind, I study symmetric functions (characters and their generalizations) and determinant/Pfaffian identities ([2]).

Plane partitions are certain arrays of non-negative integers, which can be visualized as a stack of unit cubes (see the middle figure below). And alternating sign matrices are certain matrices with entries 1, 0 and −1 (see the right figure below), which are a generalization of permutation matrices. These objects were defined with purely combinatorial motivation, but they turned out to have relations with representation theory, statistical physics and so on. In my research, I enumerate certain classes of plane partitions, alternating sign matrices and related combinatorial objects by revealing hidden algebraic structures ([3]). In particular, I am interested in mysterious relationship between alternating sign matrices and totally symmetric self-complementary plane partitions.





$$\begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

Major Publications:

[1] S. Okada, Algebras associated to the Young–Fibonacci lattice, Trans. Amer. Math. Soc., **346** (1994), 549 – 568.

[2] S. Okada, Applications of minor summation formulas to rectangular-shaped representations of classical groups, J. Algebra **205** (1998), 337 – 367.

[3] S. Okada, Enumeration of symmetry classes of alternating sign matrices and characters of classical groups, J. Algebraic Combin. **23** (2006), 43 – 69.

[4] S. Okada, "Representation Theory of Classical Groups and Combinatorics", Baifukan, 2006 (in Japanese).

[5] M. Ishikawa and S. Okada, Identities for determinants and Pfaffians, and their applications, Sugaku **62** (2010), 85–114 (in Japanese).

Education and Appointments:

1990 Doctor of Science, University of Tokyo
1990 Research Associate, Nagoya University
1995 Associate Professor, Nagoya University
2006 Professor, Nagoya University

Message to Prospective Students:

I think that combinatorics is one of the most active and interesting areas in mathematics. Combinatorial problems or structures can be found in many branches of mathematics (and science), and the methods of algebraic combinatorics are applicable to these problems. So it is important to take interest not only in combinatorics but also in other related fields.

The interested students can start their study in combinatorics and its connection to algebra and representation theory with one of the following books.

1. R. P. Stanley, "Enumerative Combinatorics", Vol. 1 (2nd ed.), Vol. 2, Cambridge Univ. Press, 2012, 1999.
2. W. Fulton, "Young Tableaux : With Applications to Representation Theory and Geometry", Cambridge Univ. Press, 1996.
3. I. G. Macdonald, "Symmetric Functions and Hall Polynomials", Oxford Univ. Press, 1995.
4. J. Hong and S.-J. Kang, "Introduction to Quantum Groups and Crystal Bases", Amer. Math. Soc., 2002
5. A. Björner and F. Brenti, "Combinatorics of Coxeter groups", Springer, 2005.

Basic knowledge of linear algebra and abstract algebra is a necessary prerequisite for most of these books. Also the students can start their research activities in combinatorics at a relatively early stage.

SHIROMIZU, Tetsuya Professor

Office: Rm 445 in Sci. Bldg. A
Phone: +81 (0) 52−789−5577 (ext. 5577)
Email: shiromizu@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~shiromizu/

Membership of Academic Societies:
The Physical Society of Japan
The Astronomical Society of Japan

Research Interest:

- General relativity
- Cosmology
- Gravity

Research Summary:

I am studying general relativity and cosmology. Due to the recent development in the observations/experiments for the universe, we could have the standard model for the universe now. However, we encounter various new issues. To address such things, I often employed the differential geometry to have unique consequences. The keywords for my research would be black hole spacetimes, asymptotic structure of spacetimes, string-inspired higher dimensional model for cosmology, positive mass theorem and so on. For example, using the second variation formula for the minimal surface, I could show the presence of the upper bound for black hole area in asymptotically deSitter spacetimes. And I showed the uniqueness of static black holes in higher dimensions. I prefer non-trivial application of differential geometry or so into general relativity and cosmology.

Major Publications:

[1] T. Shiromizu, K. Nakao, H. Kodama and K. -I. Maeda, "Can large black holes collide in de Sitter space-time? An inflationary scenario of an inhomogeneous universe," Phys. Rev. D **47**, 3099 (1993).

[2] T. Shiromizu, K. -i. Maeda and M. Sasaki, "The Einstein equation on the 3-brane world," Phys. Rev. D **62**, 024012 (2000).

[3] G. W. Gibbons, D. Ida and T. Shiromizu, "Uniqueness and nonuniqueness of static black holes in higher dimensions," Phys. Rev. Lett. **89**, 041101 (2002).

[4] K. Tanabe, S. Kinoshita and T. Shiromizu, "Asymptotic flatness at null infinity in arbitrary dimensions," Phys. Rev. D **84**, 044055 (2011).

[5] M. Nozawa and T. Shiromizu, "Modeling scalar fields consistent with positive mass" Phys. Rev. D **89**, 023011(2014).

Awards and Prizes:

- 2005 20th Nishinomiya-Yukawa Memorial Awards
- 2006 The Young Scientists' Prize(The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology)
- 2010 Daiwa Adrian Prize (for UK-Japan teams(Japanese Team Leader:M.Sasaki))

Education and Appointments:

1996	Department of Physics, Kyoto University PhD
1996	Assistant Professor, Department of Physics, The University of Tokyo
2002	Associate Professor, Department of Physics, Tokyo Institute of Technology
2008	Associate Professor, Department of Physics, Kyoto University
2014	Professor, Department of Mathematics, Nagoya University

Message to Prospective Students:

A typical application of differential geometry to physics is in general relativity(GR). GR predicts the presence of black holes and expanding universe. Meanwhile the superstring theory, which is a theory of physics for everything, is formulated in higher dimensions. So the higher dimensional GR is also interesting research field.

In my seminar,

R. M. Wald, General Relativity, Chicago University Press.

will be used. Depending student's interest, we will consider astrophysics and cosmology too. In addition, I encourage graduate student report new/important papers to look for the topics for master/doctor thesis. I think that the minimum way to have the original work is good discussion/chat. They make student's understanding of study deep one.

Office: Rm 303 in Math. Bldg.
Phone: +81 (0) 52−789−2544 (ext. 2544)
Email: sugimoto@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~sugimoto/index-e.html
Membership of Academic Societies:
The Mathematical Society of Japan

Research Interest:

- partial differential equations
- Fourier analysis

Research Summary:

Various phenomena of nature can be treated mathematically by describing them in the language of partial differential equations (PDE). Through the analysis I aim to extract new principles which comprehend concrete phenomena. As a methodology of PDE, many properties of the solutions to PDE can be deduced from their *characteristics*, and I employ this idea to investigate quantitative properties of solutions like size, regularity, and so on. Simultaneously I proceed with the study of Fourier analysis as an important tool for such analysis.

That is the summary of my research, and I explain it in detail below. The tool Fourier integral operator (FIOp) was theorized by Hörmander et al. in the beginning of 1970's, and has been applied to the study of PDE in various situation. In particular, it enables us to discuss PDE after transforming them to their normal forms. FIOp is also used to express the solutions to Cauchy problems of hyperbolic and Schrödinger equations, and from the expression we can extract information on the position of singularities and how they are propagated. In this way, peculiar information on solutions governed by PDE is inherent in FIOp as algebraic or geometric structure.

On the other hand, non-linear analysis is one of the most active research fields in the modern theory of PDE, and many complex phenomena of nature have been clarified thorough it. Knowing size or regularity of solutions to PDE is an important task because they are reflected very sensitively in phenomena. But unexpectedly, it is not a straightforward task to extract all these information from FIOp. So we need help of Fourier analysis, and sometimes we need to develop Fourier analysis itself.

With the idea of pushing ahead with the quantitative analysis of PDE via FIOp for a background, I have studied so far the following subjects:

- "L^p-estimates for hyperbolic equations"
  To determine the relation between L^p-type estimates for hyperbolic equations and the geometrical structure of their characteristics.
- "Smoothing properties of dispersive equations"
  To understand why dispersive equations have extra gain of regularity if we take integral mean in time variable.

Recently I am trying to induce estimates for solutions to PDE by transforming them to their normal forms. As a great advantage of this method, we can understand the mechanism of estimates from a high position. Having prepared theories of FIOp and function spaces as the fundamental tools, I have successfully applied them to induce smoothing estimates for dispersive equations.

Major Publications:

[1] M. Sugimoto, A priori estimates for higher order hyperbolic equations, Math. Z. **215** (1994), 519–531.

[2] M. Ruzhansky and M. Sugimoto, A smoothing property of Schrödinger equations in the critical case, Math. Ann. **335** (2006), 645–673.

[3] N. Tomita and M. Sugimoto, The dilation property of modulation spaces and their inclusion relation with Besov spaces, J. Funct. Anal. **248** (2007), 79–106.

[4] M. Ruzhansky and M. Sugimoto, Structural resolvent estimates and derivative nonlinear Schrödinger equations, Comm. Math. Phys. **314** (2012), 281–304.

[5] M. Ruzhansky and M. Sugimoto, Smoothing properties of evolution equations via canonical transforms and comparison principle, Proc. London Math. Soc. **105** (2012), 393–423

Awards and Prizes:

- 2010, Daiwa Adrian Prizes, "Phase space analysis of partial differential equations"

Education and Appointments:

1992	PhD (University of Tsukuba)
1987–1990	Research Associate (University of Tsukuba)
1990–1998	Assistant Professor (Osaka University)
1998–2008	Associate Professor (Osaka University)
2008–	Professor (Nagoya University)

Message to Prospective Students:

PDE and Fourier analysis are tightly connected to each other, and are still developing under their mutual interaction. I advise students to pick one topic in either subject (or both subjects) and study it keeping other subject within his insight. The aim of this procedure is to get at least one specialty of their own. Some examples of possible textbooks are listed below:

1. G. B. Folland, Introduction to Partial Differential Equations, Princeton University Press 1995
2. G. Eskin, Lectures on Linear Partial Differential Equations, American Mathematical Soc. 2011
3. E. M. Stein, Harmonic analysis: real-variable methods, orthogonality, and oscillatory integrals, Princeton University Press 1993
4. L. Grafakos, Classical Fourier Analysis, Springer 2008
5. K. Gröchenig, Foundation of Time-Frequency Analysis, Birkhäuser 2001

For further study, I often encourage students to read (and write if possible) research papers.

Office: Rm 459 in Sci. Bldg. A
Phone: +81 (0)52−789−4830 (ext. 4830)
Email: hiroshis@math.nagoya-u.ac.jp
Membership of Academic Societies:
MSJ (The Mathematical Society of Japan)

Research Interest:

- Algebraic number theory
- Ideal class group
- Capitulation problem

Research Summary:

An algebraic integer is a complex number which is a root of a monic polynomial

$$X^n + a_1X^{n-1} + \cdots + a_{n-1}X + a_n \qquad (a_1, \ldots, a_n \in \mathbb{Z},\ n \geqq 1)$$

with rational integer coefficients. An algebraic number field K is an extension of the rational number field $\mathbb{Q}$ of finite degree. We call the ring O_K consisting of the algebraic integers contained in K the ring of integers of K. Furtwängler showed the Principal Ideal Theorem which states that every ideal of O_K becomes principal in the ring of integers of the Hilbert class field $H(K)$ (namely the maximal unramified abelian extension) of K. In capitulation problem, we study ideals which become principal in the ring of integers of an extension. In [1], we obtained that for any intermediate field L of $H(K)/K$, the number of ideal classes of K which become principal in L is divisible by the degree $[L : K]$ of the extension L/K. The paper [2] is a generalization which contains Tannaka–Terada's Principal Ideal Theorem.

In recent years, I am interested in real quadratic fields of class number 1.

Major Publications:

[1] H. Suzuki, A generalization of Hilbert's theorem 94, Nagoya Math. J., **121** (1991), 161 – 169.

[2] H. Suzuki, On the Capitulation Problem, Advanced Stud. in Pure Math., Class Field Theory – Its Centenary and Prospect, **30** (2001), 483 – 507.

[3] Y. Odai and H. Suzuki, The rank of the group of relative units of a Galois extension II, Tohoku Math. J. **56** (2004), 367 – 370.

Education and Appointments:

1991 Lecturer, Nagoya University
2007 Associate Professor, Nagoya University

Message to Prospective Students:

In algebraic number theory, calculations of examples by hand often need enormous time and efforts, so I suggest in my small class using software packages KASH, PARI etc.

Office: Rm 433 in Sci. Bldg. A
Phone: +81 (0) 52−789−2834 (ext. 2834)
Email: takahashi@math.nagoya-u.ac.jp
Web-site: https://www.math.nagoya-u.ac.jp/~takahashi/
Membership of Academic Societies:
MSJ (The Mathematical Society of Japan)

Research Interest:

- Commutative Algebra
- Representation Theory of Algebras

Research Summary:

Commutative algebra is the theory of commutative rings. This theory has close relationships with many areas of mathematics, including algebraic geometry, number theory, representation theory, noncommutative algebra, algebraic topology, algebraic combinatorics, computational algebra, and recently, even physics and algebraic statistics. I have mainly been working in the boundary between commutative algebra and representation theory of algebras.

The subject of representation theory of algebras is to understand the structure of the module category, i.e., the category of finitely generated modules, over a given noetherian algebra. The structure of the module category will be clarified if we can classify all the indecomposable finitely generated modules, but this is regarded as "impossible" in general. (Most algebras have wild representation type, and it is known that over such an algebra it is hopeless to classify the indecomposable finitely generated modules.) Thus, in modern representation theory of algebras, the main approach to try to understand the structure of the module category is to investigate subcategories of the module category having good properties and triangulated categories associated to the module category, like derived categories, stable categories and singularity categories.

My research area is "representation theory of commutative rings." Namely, the purpose of my study is to understand the structure of the module category of a given commutative noetherian ring. Representation theory of Cohen–Macaulay rings was born in the 1970s as a higher dimensional version of representation theory of finite dimensional algebras, which explores the subcategory of the module category of a Cohen–Macaulay ring consisting of (maximal) Cohen–Macaulay modules. The meaning of Cohen–Macaulay rings has initially been found in the ideal theory as a local theory of algebraic geometry. These rings are important from the viewpoints of both homological algebra and algebraic combinatorics, and have been playing a crucial role in modern commutative algebra. I have been studying module categories of commutative rings and their subcategories and associated triangulated categories, always having in mind Cohen–Macaulay rings, especially Gorenstein rings, which possess plenty of dualities and symmetries. My current biggest interests are in classifying resolving subcategories of module categories and thick subcategories of derived categories.

Major Publications:

[1] R. Takahashi, Classifying thick subcategories of the stable category of Cohen–Macaulay modules, *Adv. Math.* **225** (2010), no. 4, 2076–2116.

[2] R. Takahashi, Contravariantly finite resolving subcategories over commutative rings, *Amer. J. Math.* **133** (2011), no. 2, 417–436.

[3] H. Dao; R. Takahashi, Classification of resolving subcategories and grade consistent functions, *Int. Math. Res. Not.* (2015), no. 1, 119–149.

[4] S. B. Iyengar; R. Takahashi, Annihilation of cohomology and strong generation of module categories, *Int. Math. Res. Not.* (2016), no. 2, 499–535.

[5] H. Matsui; R. Takahashi, Thick tensor ideals of right bounded derived categories, *Algebra Number Theory* **11** (2017), no. 7, 1677–1738.

Awards and Prizes:

- 2004, MSJ Takebe Prize, "Homological studies of Cohen–Macaulay rings"
- 2020, MSJ Algebra Prize, "Subcategories of module categories of commutative rings"

Education and Appointments:

2000	BhSc at Kyoto University
2004	Ph.D. at Okayama University
2006	Assistant Professor, Shinshu University
2009	Associate Professor, Shinshu University
2012	Associate Professor, Nagoya University
2022	Professor, Nagoya University

Message to Prospective Students:

"Commutative algebra is a beautiful and deep theory in its own right" — This sentence appears at the beginning of the introduction of [3]. When I was a third-year undergraduate, I met a mathematician, who became my Ph.D. advisor later, and he gave me motivations to study commutative algebra. As soon as I started studying commutative algebra, its systematic theory very much attracted me. Commutative algebra is an area whose entry level is low; one can start studying it only by basic knowledge on rings given in the undergraduate course. If you have not yet studied commutative algebra itself, go to a bookstore or a library to get and study [3]. Then, even if you face a place which you cannot understand (i.e., which you cannot explain in the case where someone asks you), do not skip it. Consider each sentence until you understand it.

The book [3] has been thought of as the most excellent book in commutative algebra all over the world, and probably all of those who deal with commutative algebra possess this book. Basically one can understand it by undergraduate algebra, that is, linear algebra, group theory, ring theory and general topology. If [3] turns out to be too difficult for you, you can begin with [1] alternatively.

After learning [3], you should move to [2]. This book contains a lot of basic facts which are usually assumed as preliminary knowledge in papers on commutative algebra. Thus classical commutative algebra can be enjoyed enough by studying [3], but to understand recent results in commutative algebra and to get your own results, you need knowledge given in [2]. The book [4] handles representation theory of Cohen–Macaulay rings, and contains classification of Gorenstein rings of finite Cohen–Macaulay representation type and Cohen–Macaulay modules over them, which has been completed in the 1980s. One can understand this book after learning [2]. Since this is deeply interesting, I recommend you to study it.

[1] M. F. Atiyah; I. G. MacDonald, *Introduction to commutative Algebra*, Westview Press, 1994.

[2] W. Bruns; J. Herzog, *Cohen-Macaulay rings*, Cambridge University Press, 1998.

[3] H. Matsumura, *Commutative ring theory*, Cambridge University Press, 1989.

[4] Y. Yoshino, *Cohen-Macaulay modules over Cohen-Macaulay rings*, Cambridge University Press, 1990.

Office: Rm 506 in Math. Bldg.
Phone: +81 (0) 52–789–2424 (ext. 2424)
Email: sho.tanimoto@math.nagoya-u.ac.jp
Web-site: https://shotanimoto.wordpress.com

Research Interest:

- Algebraic Geometry
- Arithmetic Geometry
- Diophantine Geometry

Research Summary:

The study of rational solutions to a system of polynomial equations with rational coefficients is called as *Diophantine geometry* whose origin dates back at least to the age of Greece. For example, Fermat's last theorem claims that a naive equation $x^n + y^n = z^n$ possesses only trivial solutions when $n \geq 3$, and this theorem has been proved by Wiles using highly advanced mathematics.

A modern approach in Diophantine geometry is to consider rational solutions as points on a geometric object called an *algebraic variety* which is defined by a system of polynomial equations, and this is a reason why rational solutions are called as *rational points*. My research mainly involves applying recent advances of higher dimensional algebraic geometry to problems in Diophantine geometry and applying the perspective of arithmetic geometry to problems in algebraic geometry.

My research has been centered around Manin's conjecture which is a conjectural asymptotic formula for the counting function of rational points on a Fano variety and the asymptotic formula is expressed in terms of birational invariants of the underlying variety. I have been studying birational geometric aspects of Manin's conjecture using higher dimensional algebraic geometry, and I also have been applying techniques from analytic number theory to prove Manin's conjecture for certain homogeneous spaces. So far my research can be summarized in three categories:

- We proposed a conjectural description of exceptional sets appearing in Manin's conjecture and proved that it is a thin set using the minimal model program. ([1], [7])
- We applied the above study of birational geometry of Manin's conjecture to problems on moduli spaces of rational curves on Fano varieties. ([2], [5], [8], [9])
- We proved Manin's conjecture and its variants for certain homogeneous spaces using the method of height zeta functions. ([4], [6])

Recently I am interested in homological stability of moduli spaces of rational curves and the motivic version of Manin's conjecture.

Major Publications:

[1] B. Lehmann and S. Tanimoto, On the geometry of thin exceptional sets in Manin's conjecture, Duke Math. J. **166** (2017), no. 15, 2815–2869,

[2] B. Lehmann and S. Tanimoto, Geometric Manin's conjecture and rational curves, Compos. Math. **155** (2019), no. 5, 833–862,

[3] S. Tanimoto, On upper bounds of Manin type, Algebra Number Theory **14** (2020), no. 3, 731–761,

[4] D. Loughran, R. Takloo-Bighash, and S. Tanimoto, Zero-loci of Brauer group elements on semi-simple algebraic groups, J. Inst. Math. Jussieu, **19** (2020), no. 5, 1467–1507,

[5] B. Lehmann and S. Tanimoto, Rational curves on prime Fano threefolds of index 1, J. Algebraic Geom., **30** (2021), no. 1, 151–188,

[6] M. Pieropan, A. Smeets, S. Tanimoto, and A. Várilly-Alavarado, Campana points of bounded height on vector group compacrifications, Proc. Lond. Math. Soc, **123** (2021), no. 1, 57–101,

[7] B. Lehmann, A. K. Sengupta, and S. Tanimoto, Geometric consistency of Manin's conjecture, Compos. Math. **158** (2022), no. 6, 1375–1427

[8] B. Lehmann and S. Tanimoto, Classifying sections of del Pezzo fibrations, I, to appear in J. Eur. Math. Soc. (JEMS),

[9] B. Lehmann, E. Riedl, and S. Tanimoto, Non-free sections of Fano fibrations, submitted,

Education and Appointments:

2012	Courant Institute of Mathematical Sciences, New York University, Ph.D.
2012	G.C. Evans Instructor, Department of Mathematics, Rice University
2015	PostDoc, Department of Mathematical Sciences, the University of Copenhagen
2018	Associate Professor, Priority Organization for Innovation and Excellence, Kumamoto University
2021	Associate Professor, Graduate School of Mathematics, Nagoya University

Message to Prospective Students:

Undergraduate students need to study the foundation of algebraic geometry, i.e., schemes and cohomology, and I have been using [2] for my seminar. To understand these, students need to be familiar with commutative algebra, and this can be acquired by reading [1] or [3].

I want my MS students to study higher dimensional algebraic geometry. Possible topics are: (1) the minimal model program (2) Positivity of divisors (3) Theory of rational curves. To understand (1), [4] is a standard textbook, but this book does not contain recent advances in the MMP such as BCHM. These advances can be studied by reading original papers after completing [4]. To learn (2), [5] are best textbooks. I have not read these recently and I am interested in reading them again. For (3), [6] is a good textbook. [7] is a more serious book, but it is a bit challenging to read.

MS students in their second year and Doctor students should conduct their own research. Topics of my recent students are: (1) Examples of exceptional sets in Manin's conjecture, (2) Geometric Manin's conjecture for Fano varieties, (3) Constructions of derived categories. Any topics in algebraic geometry and arithmetic geometry are welcome, so let me know if you have any problem you are interested in.

[1] M. F. Atiyah and I. G. MacDonald, Introduction to Commutative Algebra,

[2] R. Hartshorne, Algebraic Geometry, Springer

[3] S. Bosch, Algebraic Geometry and Commutative Algebra, Springer

[4] J. Kollár and Sh. Mori, Birational Geometry of Algebraic Varieties, Cambridge
[5] R. Lazarsfeld, Positivity in Algebraic Geometry I, II, Springer
[6] O. Debarre, Higher Dimensional Algebraic Geometry, Springer
[7] J. Kollár, Rational curves on Algebraic Varieties, Springer

Office: Rm 457 in Sci. Bldg. A
Phone: +81 (0)52−789−4533 (ext. 4533)
Email: yutaka@math.nagoya-u.ac.jp
Membership of Academic Societies:
(MSJ) The Mathematical Society of Japan

Research Interest:

- Mathematical Analysis of Fundamantal Equations for Fluid Mechanics
- Fourier Analysis

Research Summary:

My main research interest is in mathematical analysis of fundamental equations for fluid mechanics. Recently, I study motion of non-Newtonian fluids (fluids of macromolecule such as gel and ketchup). Navier-Stokes equations which describes the motion of incompressible Newtonian fluids is the following:

$\partial_t u - \mathrm{div}(\nu Du) + u \cdot \nabla u + \nabla p = f$, div $u = 0$

Here, u is a velocity vector field of the fluid, $Du = \frac{1}{2}\left(\nabla u + (\nabla u)^T\right)$, p is a pressure scalar field and ν is a viscosity of the fluid which is a positive constant and f is an external force. u and p are unknown functions and a problem of solvability of the system under suitable initial and boundary data is initial-boundary-value problem of Navier-Stokes equations. Main characteristics of the equations is non-linearity, having several unknowns and incompressibility condition div$u = 0$. The analysis of the equations are difficult because one couldn't use a maximum principle for the solutions which holds for certain non-linear heat equations. In fact, global in time existence of the classical solutions for the Navier-Stokes equations in 3-dim. space is a famous open problem and is one of seven millennium problems posed by Clay Mathematics Institute. There have been many studies about local in time existence of classical solutions and global in time existence of classical solutions concerning the equation.

My recent research interest is in non-Newtonian fluids which is described by the equations whose difference with the Navier-Stokes equations is that the viscosity is a non-constant function which depends on the largeness of Du. Among the equations which describes various non-Newtonian fluids is power-law fluid equations in which the Laplacian part of the Navier-Stokes equations are replaced by the p-Laplacian type operator. The solvability of the equations depends on the value of p. Maximal monotone operator theory is needed to show the existence of global weak solution and in 60's Ladyzhenskaya and Lions show the unique existence of global weak solutions for large p. To show the existence of weak solutions for smaller p, Fourier analytic method called "Lipschitz truncation method" is needed and it is studied well by a group around Ruzicka after '00. For an analysis of two-phase Newtonian fluids, such as oil and water, L^p estimates (or, L^pmaximal regularity) of its linearized equation around initial data is needed. A similar method can be employed for single power-law fluids and the local existence of its classical solutions were shown by Bothe-Pr"uss('07).

I am studying problems related with global existence of weak solution for two-phase power-law fluid and local existence of its classical solution. I am also interested in a study of deeper property of a linearized equation of a single power-law fluid equation and related Probability Theory and Fourier Analysis.

Major Publications:

[1] H. Abels and Y. Terasawa, On Stokes operators with variable viscosity in bounded and unbounded domains, Math. Ann. **344** (2009), 381–429.

[2] H. Abels and Y. Terasawa, Non-homogeneous Navier-Stokes systems with order-parameter-dependent stresses, Math. Methods Appl. Sci. **33** (2010), 1532–1544.

[3] H. Abels, L. Diening and Y. Terasawa, Existence of weak solutions for a diffuse interface model of non-Newtonian two-phase flows, Nonlinear Anal. Real World Appl. **15** (2014), 149–157.

Education and Appointments:

2007	Graduated from Gradate school of Mathematics at Hokkaido University
2009	Research Assistant, Tohoku University
2010	Project Researcher, The University of Tokyo
2011	JSPS Fellow, The University of Tokyo
2012	Project Research Associate, The University of Tokyo
2014	Associate Professor, Nagoya University

Message to Prospective Students:

To investigate a motion of incompressible viscous fluids, one needs to master basic theories on Partial Differential Equations, Functional Analysis and Fourier Analysis etc. In the seminar, it is preferable that students first master one of these topics well and then later study students study more advanced topics such as solvability theory of incompressible viscous fluid equations based on it. It is also preferable that students expand their knowledge of other fields in the course of their study of advanced topics. If students hope, both basic course and advanced course could be held.

I list a candidate for texts used in the course, but students could choose other books.

1. S. Krantz, A Panorama of Harmonic Analysis, The Mathematical Association of America.
2. T. Hytönen, Weighted Norm Inequalities, Lecture Note available on Web.
3. H. Tanabe, Functional Analytic Methods for Partial Differential Eqautions, CRC Press.
4. H. Brezis, Functional Analysis, Sobolev Spaces and Partial Differential Equations, Springer.
5. M. Giaquinta, L. Martinazzi, An introduction to the regularity theory for elliptic system, harmonic maps and minimal graphs, Edizioni Della Normale.
6. A. McIntosh, Operator Theory - Spectra and Functional Calculi, Lecture Note available on Web.

Students who would like to take our master course small class are required to have sound knowledge of basic facts in Calculus, Ordinary Differential Equation, Complex Analysis, Lebesgue Integration Theory and Functional Analysis. If a student doesn't have enough knowledge to study in the course, he or she needs to study it in case it is needed. After these studies, one studies more specialized topics such as analysis of motion of incompressible fluids. One could also choose another subject related to Fourier analysis or PDE.

In their Doctor Course, I advise students on more advanced topics. In Doctor Course, students' hope is valued concerning a choice of their research topics.

Office: Rm 301 in Math. Bldg.
Phone: +81 (0) 52−789−2823 (ext. 2823)
Email: ueda@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~ueda/

Research Interest:

- Operator algebras
- Non-commutative analysis

Research Summary:

I have studied various topics based on operator algebras. The highlights of operator algebras are: fights against "non-commutative phenomena" and overcoming obstacles from "infinite dimensionality". Finding suitable algebraic formulations is important in view of "non-commutativity", and it is interesting that we need skills of analysis to overcome obstacles from "infinite dimensionality". Operator algebras are so cool and quite an interesting and broad subject in mathematics.

The keywords of my research include: von Neumann algebras, free product (with amalgamation), HNN extension, quantum group, subfactor, Jones index, ergodic equivalence relation, free probability theory, random matrix, non-commutation function space.

Major Publications:

[1] Yoshimichi Ueda, A minimal action of the compact quantum group $\mathrm{SU}_q(n)$ on a full factor. Journal of Mathematical Society of Japan, Vol. 51 (1999), 449 – 461.

[2] Dimitri Shlyakhtenko and Yoshimichi Ueda, Irreducible subfactors of $L(\mathbb{F}_\infty)$ of index $\lambda > 4$. Journal für die reine und angewandte Mathematik, Vol. 548 (2002), 149 – 166.

[3] Fumio Hiai, Denis Petz and Yoshimichi Ueda, Free transportation cost inequalities via random matrix approximation. Probability Theory and Related Fields, Vol. 130 (2004), 199 – 211

[4] Fumio Hiai, Takuho Miyamoto and Yoshimichi Ueda, Orbital approach to microstate free entropy. International Journal of Mathematics, Vol. 20 (2009), 227–273.

[5] Yoshimichi Ueda, On peak phenomena for non-commutative H^∞. Mathematische Annalen, Vol. 343 (2009), 421–429.

[6] Yoshimichi Ueda, Factoriality, type classification and fullness for free product von Neumann algebras. Advances in Mathematics, Vol. 228 (2011), 2647–2671.

[7] Yoshimichi Ueda, Discrete cores of type III free product factors. American Journal of Mathematics, Vol. 138 (2016), 367–394.

[8] Yoshimichi Ueda, Matrix liberation process I: Large deviation upper bound and almost sure convergence. Journal of Theoretical Probability, to appear.

Education and Appointments:

Mar. 1999	Completed Graduate program, Kyushu University
Apr. 1999	Research Associate, Hiroshima University
Sep. 1999	Doctoral degree (Ph.D.) from Kyushu University
Apr. 2002	Associate Professor, Kyushu University
Oct. 2017	Professor, Nagoya University

Message to Prospective Students:

You should finish to learn calculus, linear algebra, general topology, complex analysis, measure theory, and elementary functional analysis prior to your entrance to our graduate school for your study on operator algebras. You can obtain enough knowledge on complex analysis, measure theory, and elementary functional analysis from two very fine books "Real and Complex Analysis" by W. Rudin and "A Guide to Functional Analysis" by S.G. Krantz. These three subjects form an important basis for the study of any branches of mathematical analysis. It is also very nice if you have already learnt a little about abstract algebra and geometry as well as probability theory.

I usually advise my students to study topics, which are different from my research topics as well as other student's ones under my guidance, within operator algebras in a broad sense. This is because I hope that any student studies hard as an independent and important member of our group.

Office: Rm 305 in Math. Bldg.
Phone: +81 (0)52−789−2461 (ext. 2461)
Email: uzawa@math.nagoya-u.ac.jp

Membership of Academic Societies:
BSP (The Biophysical Society of Japan),
SMF (Société Mathématique de France)

Research Interest:

- Representation Theory of Groups
- Compactifications
- Applied Mathematics

Research Summary:

Representation theory of groups is a relative new-comer to mathematics: it started with a paper by Frobenius titled "On the theory of group characters" in 1887. It was first a theory of characters, and it was Schur that formulated the results in terms of representations, namely homomorphisms from a group G to the general linear group $GL(V)$.

Representation developed rapidly, and is crucial to many fields in mathematics, physics, and applications.

The most natural way to produce examples of groups is to look at the group of symmetries preserving a structure. For example, one can take a vector space V over a finite field $\mathbb{F}_q$ and look at the group of linear isomorphisms. This is a finite group which is almost a simple group. Simple groups are the fundamental building blocks in group theory, and one interesting fact is that all but finitely many simple groups arise as groups preserving a geometry, and thus can be classified using Dynkin diagrams. Dynkin diagrams classify simple compact Lie groups; this is yet another example of the continuity joining finite groups and simple groups over various fields.

I have worked on real groups, and introduced a geometric method to give Matsuki correspondencees ([1]). I am also working on the use of covariant compactifications of group varieties and its applications to representation theory [2], and symmetric varieties over fields of arbitrary characteristics [1].

I am now also working on problems that arise from industry and medical research. Recent progress in stem cell research offers various interesting mathematical problems: the field is far from mature, and novel mathematical methods may arise from such research.

Major Publications:

[1] T. Uzawa: Symmetric varieties over arbitrary fields , C. R. Acad. Sci. Paris Sér. I Math. **333** (2001), no. 9, 833–838,

[2] T. Uzawa: Compactifications of symmetric varieties and applications to representation theory, Sūrikaisekikenkyūsho Kōkyūroku **10826** (1999), 137–142.

[3] Inui, N. and Katori, M. and Uzawa, T.: Duality and universality in non-equilibrium lattice models, J. Phys. A **28** (1995), no. 7, 1817–1830.

[4] Mirković, I. and Uzawa, T. and Vilonen, K.: Matsuki correspondence for sheaves, Invent. Math. **109**(1992) no. 22, 231–245.

[5] T. Yamada, H.Akamatsu, S. Hasegawa, N. Yamamoto, T.Yoshimura, Y.Hasebe, Y. Inoue, H. Mizutani, T.Uzawa, K. Matsunaga, S. Nakata: Age-related changes of p75 Neurotrophin receptor-positive adipose-derived stem cells, J. of Dermatological Science **58** (2010), no. 1, 36–42.

Education and Appointments:

1990 Assistant Professor, Penn State
1991 Assistant Professor, Tokyo University
1992 Associate Professor, Tohoku University
1997 Associate Professor, Rikkyo University
2002 Professor, Nagoya University

Message to Prospective Students:

The interplay between theory of groups and representation theory is fascinating, and the connection with automorphic forms is one of the most tantalizing connections to be found in mathematics. I prefer to work with geometric methods, a student should have strong background in differential geometry and algebraic geometry. My work in applied fields are scattered, but work related to stem cells are starting to take form; this is a rapidly progressing field, and it is hard to say what are the basic mathematical tools.

[1] I.M.Gelfand, M.I. Graev, I. Piatetski-Shapiro, Representation theory and automorphic functions.
[2] R.Hartshorne: Algebraic geometry.
[3] D. Vogan: Unitary Representations of Reductive Lie Groups
[4] D. MacKay:Information Theory, Inference, and Learning Algorithms. http://www.inference.phy.cam.ac.uk/itprnn/book.html
[5] W.Fulton: Intersection theory.

Office: Rm 441 in Sci. Bldg. A
Phone: +81 (0) 52–789–5595 (ext. 5595)
Email: yanagida@math.nagoya-u.ac.jp
Web-site: http://www.math.nagoya-u.ac.jp/~yanagida/index.html
Membership of Academic Societies:
The Mathematical Society of Japan

Research Interest:

- Representation Theory
- Algebraic Geometry
- Mathematical Physics

Research Summary:

My research areas are representation theory and algebraic geometry, in particular the topics related to mathematical physics and special functions.

My interest in algebraic geometry is mainly on the derived category of sheaves on algebraic varieties. Two keywords may be named: Fourier-Mukai transforms and Bridgeland stability conditions. On these topics, I have co-authored papers [3] and [10].

My interest in representation theory is mainly on quantum algebras, in particular quantum groups, Hall algebras and vertex algebras. In the collaboration [1], we investigated the quantum integrable system associated to Macdonald symmetric functions using representation theory of $\mathfrak{gl}_1$ quantum toroidal algebra (also called the Ding-Iohara-Miki algebra). Since then, I have been studying the Macdonald polynomials and the (double) affine Hecke algebras associated to affine root systems [8, 9].

As an intersection of algebraic geometry and representation theory, I have been studying geometric aspects of vertex algebras. In [6], I introduced the gluing construction of vertex algebras of class S in the derived setting, using the derived symplectic/Poisson geometry. In [7], I introduced an analogue of the canonical Li filtration of a vertex algebra for an arbitrary SUSY vertex algebra, and relate the representation theory of superconformal vertex algebras to the Poisson geometry of the associated superschemes.

Recently, I collaborated with the doctor student Yusuke Nishinaka-san [4, 5] to establish the algebraic operad encoding the structure of SUSY vertex algebras, and with Masamune Hattori-san [2] to introduce the dynamical Ding-Iohara algebroids which unify the elliptic quantum groups and Ding-Iohara quantum algebras.

Major Publications:

[1] B. Feigin, K. Hashizume, A. Hoshino, J. Shiraishi, S. Yanagida, *A commutative algebra on degenerate* $\mathbb{CP}^1$ *and Macdonald polynomials*, J. Math. Phys. **50** (2009), no. 9, 095215, 42 pp.

[2] M. Hattori, S. Yanagida, *A dynamical analogue of Ding-Iohara quantum algebras*, preprint (2022), arXiv:2210.02777, 42pp.

[3] H. Minamide, S. Yanagida, K. Yoshioka, *The wall-crossing behavior for Bridgeland's stability conditions on abelian and K3 surfaces*, J. Reine Angew. Math. **735** (2018), 1–107.

[4] Y. Nishinaka, S. Yanagida, *Algebraic operad of SUSY vertex algebra*, preprint (2022), arXiv:2209.14617, 42pp.

[5] Y. Nishinaka, S. Yanagida, *Algebraic operad of SUSY Poisson vertex algebra*, preprint (2023), arXiv:2305.00714, 42pp.

[6] S. Yanagida, *Derived gluing construction of chiral algebras*, Lett. Math. Phys. **111** (2021), Article no. 51, 103pp.

[7] S. Yanagida, *Li filtrations of SUSY vertex algebras*, Lett. Math. Phys., **112** (2022), Article no. 103, 77pp.

[8] K. Yamaguchi, S. Yanagida, *Specializing Koornwinder polynomials to Macdonald polynomials of type B, C, D and BC*, J. Algebraic Combin. (2022), online published, 56pp.

[9] K. Yamaguchi, S. Yanagida, *A review of rank one bispectral correspondence of quantum affine KZ equations and Macdonald-type eigenvalue problems*, RIMS Kokyuroku (2023) 36pp.; arXiv:2211.13671.

[10] S. Yanagida, K. Yoshioka, *Semi-homogeneous sheaves, Fourier-Mukai transforms and moduli of stable sheaves on abelian surfaces*, J. Reine Angew. Math. **684** (2013), 31–86.

Education and Appointments:

2012 Ph.D. Mathematics at Kobe University
2012 JSPS PD at RIMS, Kyoto University
2012 Assistant Professor, RIMS, Kyoto University
2016 Associate Professor, Nagoya University

Message to Prospective Students:

Undergraduate students interested in algebraic geometry or (algebraic/geometric) representation theory will be welcomed. The reading seminar will be on standard texts such as the textbooks 1,2 and 3.

I also welcome graduate students who are willing to study Bridgeland stability conditions and related topics, or geometric representation theory of quantum algebras. For examples of particular topics, please see the books 4, 5 and 6 below.

1. R. Hartshorne, *Algebraic Geometry*, Graduate Texts in Mathematics **52**, Springer (1977).
2. T. Tanisaki, *Lie algebras and quantum groups* (in Japanese), Kyoritsu-syuppan (2002).
3. Y. Yamada, *Introduction to conformal field theory* (in Japanese), Baifukan (2006).
4. D. Huybrechts, *Fourier-Mukai transforms in algebraic geometry*, Oxford Univ. Press (2006).
5. D. Huybrechts, M. Lehn, *The geometry of moduli spaces of sheaves*, Cambridge University Press (2010).
6. E. Frenkel, D. Ben-Zvi, *Vertex algebras and algebraic curves*, 2nd edition, Mathematical Surveys and Monographs **88**, American Mathematical Society (2004).

Office: Rm 439 in Sci. Bldg. A

Phone: +81 (0) 52−789−2420 (ext. 2420)

Email: noby@math.nagoya-u.ac.jp

Web-site: http://www.math.nagoya-u.ac.jp/~noby/

Membership of Academic Societies:
MSJ (Mathematical Society of Japan)

Research Interest:

- Directed polymers in random environment
- Interacting particle systems

Research Summary:

Imagine a hydrophilic polymer chain wafting in water. Due to the thermal fluctuation, the shape of the polymer should be understood as a random object. We now suppose that the water containes randomly placed hydrophobic molecules as impurities, which repell the hydrophilic monomers which the polymer consists of. The question we address here is;

How does the impurities affect the global shape of the polymer chain?

My recent research interest centers around the above question. The above question is mathematically formulated in the framework of "directed polymers in random environment" (DPRE). This can be thought of as a model of statistical mechanics in which paths of the random walk interact with a quenched disorder (impurities). We study the phase transition of this model, which depends on the dimension of the sapce and the thermodynamic parameters.

More recently, it was recognized that the DPRE is closely connected to a certain class of interacting particle systems, as well as branching random walks in random environment. This provides us with new perspectives of the research.

Major Publications:

[1] F. Comets, N. Yoshida: Localization Transition for Polymers in Poissonian Medium. Commun. Math. Phys. (to appear)

[2] R. Fukushima, N. Yoshida On the exponential growth for a certain class of linear systems. ALEA Lat. Am. J. of Prob. Math. Stat. **9** (2012), 323–336.

[3] Y. Nagahata, N. Yoshida Localization for a Class of Linear Systems. Electron. J. Prob.**16** (2011), no. 3, 657–687

[4] F. Comets, N. Yoshida Branching Random Walks in Time-Space Random Environment: Survival Probability, Global and Local Growth Rates. J. Theoret. Prob.**24** (2010), no. 3, 657–687

Awards and Prizes:

- The 4th MSJ Analysis Prize (2005)

Education and Appointments:

1991	Assistant Professor, Kyoto University
1998	Lecturer, Kyoto University
2003	Associate Professor, Kyoto University
2013	Professor, Nagoya University

Message to Prospective Students:

The text book of the seminar for graduate students will be choosen, for example from the following subjects: Brownian motion, stochastic calculus, interacting particle systems, percolation.

Office: !! Invalid Office (Humanities Building-419)
Phone: +81 (0) 52–789–5181 (ext. 5181)
Email: cbourne@nagoya-u.jp
Web-site: https://sites.google.com/site/khomologyzone/

Membership of Academic Societies:
International Association of Mathematical Physics (IAMP),
The Mathematical Society of Japan (MSJ),
Australian Mathematical Society (AustMS)

Research Interest:

- Operator algebras
- Index theory and noncommutative geometry
- Mathematical physics

Research Summary:

Much of my research is about the application of operator algebras, noncommutative geometry and index theory to systems in non-relativistic quantum physics.

Quantum mechanical observables are represented by operators on a complex Hilbert space. We can study algebras of observables/operators to rigorously define and study various properties of the underlying physical system. Noncommutative geometry and index theory can then potentially be used to determine a system's topological properties. In more detail, we can use ideas from index theory and K-theory of operator algebras to assign a topological index to a system that serves as a mathematical phase label. Topological phase labels are invariant under deformations or small perturbations and physical systems described by topological phases, such as the quantum Hall effect, posses many novel properties.

In previous research, I studied topological phases of a variety of systems such as symmetric free-fermions [4, 5] and many-body ground states in quantum statistical mechanics with a spectral gap condition [3].

The study of index theory in quantum mechanics, where anti-linear symmetries such as time-reversal symmetry may play an important role, has also motivated new research on K-theory and index theory on real Hilbert spaces. The paper [1] develops spectral flow and index theory on real Hilbert spaces with additional 'Clifford algebra symmetries', which can be connected to quantum mechanical symmetries.

Recently I have been exploring new applications of index theory techniques in physics and beyond. An example is the paper [2], which applies methods in coarse geometry, a framework used to study the index theory of non-compact manifolds, to the ground states of superconductor models. I am also currently studying the relevance of operator algebras, noncommutative geometry and index theory in quantum walks and quantum information theory.

Major Publications:

[1] C. Bourne, A. L. Carey, M. Lesch and A. Rennie. The KO–valued spectral flow for skew-adjoint Fredholm operators. *J. Topol. Anal.*, **14**(2):505–556, 2022.

[2] C. Bourne. Locally equivalent quasifree states and index theory. *J. Phys. A: Math. Theor.*, **55**(10):104004 (38 pages), 2022.

[3] C. Bourne and Y. Ogata. The classification of symmetry protected topological phases of one-dimensional fermion systems. *Forum Math. Sigma*, **9**, Article No. e25 (45 pages), 2021.

[4] C. Bourne and B. Mesland. Index theory and topological phases of aperiodic lattices. *Ann. Henri Poincaré*, **20**(6):1969–2038, 2019.

[5] C. Bourne and A. Rennie. Chern numbers, localisation and the bulk-edge correspondence for continuous models of topological phases. *Math. Phys. Anal. Geom.*, **21**(3):16 (62 pages), 2018.

Awards and Prizes:

- Journal of Physics A (Mathematical and Theoretical) Best Paper Prize 2020

Education and Appointments:

2015	PhD (Mathematics), The Australian National University
2016	Postdoc, Friedrich-Alexander Universität Erlangen-Nürnberg
2017	JSPS Postdoc, Tohoku Univerisity
2018	Assistant Professor, Tohoku University
2018	Visiting Scientist, RIKEN iTHEMS
2023	Associate Professor, Nagoya University

Message to Prospective Students:

My research is in the field of noncommutative geometry, operator algebras and their applications in physics. Noncommutative geometry and operator algebras bring together many ideas from different areas of mathematics. This combination of mathematical ideas makes the field interesting to work in, but it also means that one needs a basic knowledge of many different mathematical fields, which can be daunting for new students. I hope to be able to help you navigate this barrier of entry and assist you to find an area of study that you find interesting. Some reference books that we use in the small-group seminar are below:

[1] J. M. Gracia-Bondía, J. C. Várilly, H. Figueroa – Elements of Noncommutative Geometry

[2] K. Davidson – C*-Algebras by Example

[3] N. E. Wegge-Olsen – K-Theory and C*-Algebras: A Friendly Approach

[4] O. Bratteli, D. Robinson – Operator Algebras and Quantum Statistical Mechanics

[5] D. D. Bleecker, B. Booß-Bavnbek – Index Theory with Applications to Mathematics and Physics

[6] N. Higson, J. Roe – Analytic K-homology