Curriculum Vitae
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PERSONAL

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Home Page:	http://www.cs.mcgill.ca/∼fukuda/
Present Status:	Tenured Full Professor of Computer Science

EDUCATION

From Sept. 1976 to Oct. 1981 :	Ph.D. Program, Combinatorics and Optimization, University of Waterloo, Canada
From April 1976 to August 1976 :	Ph.D. Program, Administration Eng., Keio University, Japan
From April 1974 to March 1976 :	Master's Program, Administration Eng., Keio University, Japan
From April 1970 to March 1974 :	Undergraduate, Administration Eng., Keio University, Japan
From April 1967 to March 1970 :	Gakushuuin Highschool, Japan

DIPLOMAS AND/OR TITLES

May 1999 :	Professor Tit., Dept. of Mathematics, ETH Zurich, Switzerland
September 1982 :	Ph.D., Combinatorics and Optimization, University of Waterloo, Canada
March 1976:	M.S., Keio University, Japan
March 1974:	B.S., Keio University, Japan

RESEARCH FIELDS

Linear, Nonlinear and Combinatorial Optimization, Computational Geometry, Design of Efficient Algorithms, Combinatorics, Oriented Matroid Theory, Combinatorial and Constructive Proof Techniques in Geometry, Development of Computer Software for Geometric and Combinatorial Computation

PROFESSIONAL ACTIVITIES

1. Referee for J. of Combinatorial Theory (Ser. A and Ser. B), Discrete Mathematics, Combinatorica, Discrete Applied Mathematics, SIAM J. Discrete Mathematics, SIAM J. Computing, Computational and Discrete Mathematics, Mathematical Programming, European J. of Combinatorics, Graphs and Combinatorics, J. of Operations Research Soc. of Japan, International

J. of Mathematics and Mathematical Sciences, European J. of Operational Research, Portugaliae Mathematica, Journal of Graph Theory, etc.

2. Editor for European J. of Combinatorics, Discrete Applied Mathematics (special Issue),

3. Ph.D. thesis or Habilitation examiner at University of Tokyo, University of Paris VI, University of Paris Sud, Tokyo Science University, Keio University, Swiss Federal Institute of Technology Lausanne (EPFL) and Zurich (ETHZ), Technical University of Berlin, University of Cantabria, University of Waterloo.

4. Organizer for Franco-Japanese Days on Combinatorics and Optimization (Annual conference started in 1988 by M. Deza and K. Fukuda, held in Tokyo, Paris, Kyoto, Grenoble, Brest, Okinawa), International Symposium on Mathematical Programming 1997 in Lausanne, International Congress of Mathematical Software 2002 in Beijing.

GRANTS/DISTINCTIONS/HONORS

2002.4–2006.3	Research Grant, Polyhedral Computation, NSERC, Canada
2003.5 –2004	Research Grant, Redundancy Removal in Convex Polyhedra and Its Applications to Optimization and Computational Geometry Swiss National Foundation, Switzerland
2000.4–2002.3	Research Grant, Polyhedral Geometry, Enumeration and Computational Complexity, Swiss National Foundation, Switzerland
1999.9.23	Editor's Choice Award 1998, Discrete Applied Mathematics for the paper "EP theorems and linear complementarity problems"
1999.5.20	Titular Professor, Swiss Federal Institute of Technology, Switzerland
1999.4	Fellow, Operations Research Society of Japan
1999.2.19–3.5	Visiting Scholar, Wolfram Research Inc., USA
1998.3.6 – 3.14	Invited Professor, Mathematical Institute of Hungarian Academic of Sciences, Budapest, Hungary
1997.10.13 – 10.26	Invited Professor, RIMS, Kyoto University, Kyoto, Japan
1995.10 – 1996.2	Invited Professor, Institute for Mathematical Research, Swiss Federal Institute of Technology, Zurich, Switzerland
1995.1– 1995.10	Invited Professor, Institute for Operations Research, Swiss Federal Institute of Technology, Zurich, Switzerland
1993–1994	Invited Professor, Department of Mathematics, Swiss Federal Institute of Technology, Lausanne, Switzerland
1993	The best paper award, OR Society of Japan for the paper "Linear Complementarity and Oriented Matroids"
1991–1994	Research Grant for New Methods in Combinatorial Optimization, Fujitsu Research Laboratory, Japan
1991–1993	Grant-in-Aids for Co-operative Research, Ministry of Education, Japan
1989–1991	RISE(Research Foundation of Software Engineering, Japan) grant for Franco-Japan joint research
1987–1988	J.S.P.S.(Japan Society for Promotion of Science) / C.N.R.S (France) Joint-Research Fellowship
1984–1989	Grant-in-Aids for Co-operative Research, Ministry of Education, Japan
1976–1981	Canadian Government Scholarship

PROFESSIONAL CAREER

Positions Occupied

2002–present	Professor, School of Computer Science, McGill University, Montreal
1996–present	Professor, Department of Mathematics, ETH Zürich and Department of Mathematics, EPF Lausanne
1995–1996	Invited Professor, Department of Mathematics, ETH Zürich
1993–1994	Invited Professor, Department of Mathematics, EPF Lausanne
1989–1996	Associate Professor, The University of Tsukuba, Tokyo, Japan
1982–1989	Assistant Professor, Tokyo Institute of Technology, Japan
1978–1981	Teaching Assistant, University of Waterloo, Waterloo, Canada
1974–1976	Teaching Assistant, Keio University, Yokohama, Japan

Detailed Description of Activities

2002–2003 I started to work at the School of Computer Science, McGill University in January 2002. The initial activities include teaching of graduate courses on Polyhedral Computation and Information Structures, a core undergraduate course on Algorithms and Data Structures, a coordination of seminars in discrete mathematics and algorithms, and directing a new undergraduate program of software engineering. I created my research lab, Polyhedral Computation Laboratory (http://www.cs.mcgill.ca/~polylab/). It has now two professors, three doctoral students and three master's students. I have organized the first workshop on polytopes, game and matroids in March 2003 at McGill's Bellairs Institute.

1996–2001 In September 1996, I started an ETHZ-EPFL joint project on Optimization and Geometric Computation with T.M. Liebling, M. Vetterli, H.-J. Lüthi and J. Nievergelt. I was involved in the project since then, and educated several doctoral students in both ETHZ and EPFL. These research activities produced a number of fundamental results and computer codes. Using these we solved many large scale optimization and geometric problems which could not be solved before. Our results have been used in recent software developments in the research group of Günter Ziegler of TU Berlin and are mentioned in the well-known LP-FAQ and Erickson's WWW page of computational geometry. Also, with a strong collaboration with Emo Welzl (ETHZ), we organized a weekly colloquium on Combinatorics, Geometric Algorithms and Optimization where we exchange new ideas with leading researchers from all over the world. In the fall of 1999, this colloquium became one of the core activities of the European Ph.D. program on Combinatorics, Geometry and Computation, jointly offered by ETH Zurich and three universities in Berlin (Freie Universität, Humboldt-Universität und Technische Universität) together with several leading universities in other European countries. Clearly my research activities shifted toward a highly international research and education for the mutual benefit of the swiss schools and the companion schools. I worked as a thesis advisor for three Ph.D. students, A. Marzetta (ETHZ), A. Andrzejak (ETHZ) and C. Lütolf (EPFL). I supervised three Ph.D. students, L. Finschi (ETHZ), T. Herrmann (ETHZ) and S. Picozzi (EPFL).

My (old) homepage My (old) homepage http://www.ifor.math.ethz.ch/ fukuda/fukuda.html provides a good account of the activities and the results produced in this period.

1989–1996 In April 1989, I moved to University of Tsukuba and became associate professor of Graduate School of Systems Management (GSSM). GSSM is the first business school created at a national university in Japan. I taught several courses such as Operations Research, Linear Programming, Combinatorial Optimization, Data Structures and Algorithms and Modern Mathematics with Case Studies. Throughout my Tsukuba years of 1989–96, I visited Europe frequently and worked with researchers in France, Switzerland, Hungary, Germany, Portugal and visiting researchers from North America. In Japan, I started a weekly research seminar on Combinatorics, Geometry and Algorithms. This seminar attracted many young researchers and graduate students from various top universities in Tokyo and its neighborhoods. Ph.D. students I supervised are Keiichi Handa, Antoine Deza and Makoto Namiki.

For the academic year 1993–94, I was invited by Department of Mathematics, EPFL, Lausanne. I carried out joint research with Prof. Thomas M. Liebling, Dr. Prodon and Dr. Francois

Margot. Also, I participated in teaching a postgraduate course jointly organized by EPFL and University of Grenoble.

For the period of Jan. 1995 through Sept. 1995, I was invited by Prof. Hans-Jakob Lüthi of ETH Zurich to work for Institute for Operations Research (IFOR) of Mathematics Department. I was then invited by Institute for Mathematical Research (FIM) of ETHZ for the Fall semester 1995 to teach a "nachdiplom" course on Combinatorics of Mathematical Programming. I returned to IFOR in Spring 1996 and continued research there. I organized a colloquium on Optimization and Combinatorics.

1981–89 In 1981, I accepted an assistant professor position at Department of Information Science, Tokyo Institute of Technology. I took this position in October 1981 and worked through March 1989. I belonged to a decision science group in the department which consists of one full professor, one associate professor and two assistant professors. I mainly worked with a then associate professor, Prof. Masakazu Kojima, to educate students of all levels (undergraduate, master, doctorate) and to carry out research in Optimization Theory, Combinatorics, Algorithms, Complexity Theory and Geometric Computation. I taught undergraduate courses/seminars on Decision Sciences, Linear Programming and Graph Theory. Also, with my initiation, a few assistant professors created a joint seminar on computer science and mathematics, which became the departmental colloquium later. I guided many students to work on linear programming, convex polytopes and computational geometry, combinatorial optimization , enumeration and oriented matroids. In particular, I supervised two Ph.D. students, Akihisa Tamura and Tomomi Matsui. I started several joint research with foreign countries. Among them, Prof. Michel Deza (CNRS, Ecole Normale Superieur, Paris), Prof. David Avis (McGill University, Montreal) and Prof. Tamas Terlaky (Etvos Lorand University, Budapest and Technical University of Delft). Also, with Prof. Deza we started an annual workshop, Franco-Japanese Days in 1987. The tenth meeting was held in Ecole Polytechnique (France) in September 1997.

1976–81 Throughout my study for a doctorate degree, I worked as a teaching assistant for several different undergraduate/graduate courses of University of Waterloo, including Calculus, Linear Algebra, Linear Programming. I also taught a undergraduate course on Linear Programming.

1974–76 During my study for a master's degree, I worked as a teaching assistant of Keio University in undergraduate mathematics courses. Only a few excellent graduate students were offered a such position.

LANGUAGES

Mother tongue	: Japanese
Very good knowledge	: English
Good knowledge	:
Elementary knowledge	: French, German

MAJOR PROFESSIONAL ACHIEVEMENTS

Combinatorial Theory of LP and LCP (1992–present)

In the paper [33] we extended the combinatorial foundation of Linear Programming (LP) to the oriented matroid complementarity theory (OMCP). This can be considered as a simplification of the abstraction of linear complementarity theory (LCP) developed earlier by M.J. Todd. In particular, we eliminated the heavy machineries to cope with degeneracy which had been standard tools in LCP. We also introduced the notion of duality in LCP and OMCP. Our duality theorem says that every OMCP (LCP) has either a primal complementary solution or a dual complementary solution if the problem is "weakly sufficient." This theorem includes the LP duality theorem and Cottle's QP duality theorem as a special case. We gave extremely simple proofs for this theorem, one recursive and one algorithmic (by extending the Criss-Cross method for Linear Programming), which are both new even when they are specialized to LCP. I received the best paper award of the year 1993 for this paper from the operations research society of Japan.

Recently we have extended the results in [15, 19, 18]. In [19, 11], we have shown the existence of a sequence of admissible pivot operations of polynomial length to an optimal solution. This can be considered as the first step toward a complete answer to the important open question as to whether there exists a *strongly* polynomial algorithm for Linear Programming.

Enumeration Complexity (1996–present)

In [62], I introduced a new notion of ENP to classify easy and hard enumeration problems. The classical notions of NP, co-NP, NP-complete, #P etc. are extremely useful but can only deal with the mathematical problems with small output, e.g. the decision problem returns 1 (true) or 0(false). The enumeration problem of listing all qualified objects addresses a much larger class of mathematical problems than the decision problem or the optimization problem. Although there are many open questions to be answered (e.g. what is the completeness in this setting?) I strongly believe the new notion ENP to be proved fundamental in complexity theory.

Geometric and Computational Combinatorics (1995–present)

Geometric objects such as convex polytopes, arrangements of hyperplanes and linear programming arise in many disciplines of science. Understanding their discrete structures is often essential in solving optimization or enumeration problems associated with these geometric objects. The theory of oriented matroids lays an ideal foundation for studying the discrete structures underlying geometric objects such as those mentioned. This foundation has been shown to be extremely useful in finding efficient algorithms to solve many basic computational problems over these geometric structures, for example [10, 4, 12, 9, 2, 1]. I gave a graduate lecture on these subjects at ETH Zurich. The lecture notes [72, 70] introduce a new area of research "Geometric and Computational Combinatorics." My future software development will be based on this foundation which I believe is both theoretically and practically sound.

Reverse Search (1992–present)

In [35], we develop a new pivot algorithm for enumerating all vertices of a convex polyhedron. This algorithm is a substantial improvement over the existing algorithms (e.g. Dyer's algorithm) since virtually no additional storage is required beyond the input data and the algorithm is more efficient than any previously known algorithms: it finds the v vertices of a polyhedron in R^d given by a nondegenerate system of n inequalities in time $O(ndv)$.

The main idea is very simple. Take any objective function on a given polyhedron with a unique optimum vertex. The new algorithm simply starts from the optimum vertex v and reverse a finite simplex method (e.g. Bland's rule) in all possible ways. By using the depth-first strategy, this reverse search algorithm finds all vertices without storing the visited vertices.

The same idea can be used to enumerate many interesting objects. In the recent paper [22], we gave various different applications of reverse search scheme, including the enumeration of all triangulations of a finite point set in the plane, that of regions of a hyperplane arrangement in R^d, etc.

I have been involved in the ZRAM project to develop a parallel implementation reverse search algorithms [14] which was used to solve the largest instances of the vertex enumeration problem. The software library is now freely available.

The most recent applications are the enumeration of k-sets for a point configuration in R^d [52], the extended convex hull computation (i.e. facet enumeration of the convex hull of k

H-polytopes in R^d) [48],[6], and the computation and [59] of the Minkowski addition of convex polytopes in R^d.

Vertex and Facet Enumeration Codes and Applications (1984–present)

In 1984, I wrote an open-source code, called PSH (polytope shelling), in Basic to generate all vertices and edges of a 3-dimensional convex polytope, based on my shelling algorithm [65]. I also wrote a 3D visualization program called PGR to polytopes computed by PSH.

In 1988, I started to develop a vertex and facet enumeration code, called pdd, in pascal. It is an implementation of the double description method by Motzkin et al and works quite efficiently for highly degenerate polyhedra.

In 1991, pdd was revised and converted to C. I made this new code cdd publicly available via anonymous ftp [79]. Then, in 1995, I made a C++ version [80] of this code, called cdd+, that runs in exact (rational) arithmetic as well as in usual floating-point arithmetic. The exact version can be used, for example, to prove certain theorems associated with convex polytopes. cdd/cdd+ is considered as one of the most efficient codes for highly degenerate and high dimensional polytopes. Some computational and theoretical results are obtained with this code, for example for cut polytopes in [31] and for analysis of ternary alloys in [28]. A recent effort includes a C-library version [78] of cdd that can be called from C/C++ programs and an interface to Mathematica.

With I. Mizukoshi, we developed a Mathematica code [83] for the vertex enumeration and made it publicly available by anonymous ftp. This is the first implementation of the reverse search algorithm [35].

Primal-Dual Algorithm for Vertex and Facet Enumeration (1996–97)

With D. Bremner and A. Marzetta, we proposed a new algorithmic scheme, primal-dual scheme [17]. This scheme exploits the duality of vertex and facet representations, and it can accelerate existing algorithms when the scheme is incorporated. Most importantly, this algorithm enables us to prove a nice duality: when the vertex (facet) enumeration is polynomially solvable in both input and output sizes for a hereditary class of polytopes, then its converse problem, the facet (vertex) enumeration problem is polynomially solvable.

Geometric Software Developments (1992–present)

We developed a Mathematica code for unfolding a 3-dimensional convex polytope and made it publicly available by anonymous ftp [76]. There are other Mathematica programs I developed such as the volume computation package for convex polytopes and the triangulation enumeration package.

We have also implemented in C/C++ many existing and new algorithms for volume computation of convex polytopes. This work [13] presents the current best technologies of computing the volume of a high-dimensional convex polytope. The codes are available and used by various researchers worldwide.

An arrangement construction algorithm [10] using reverse search has been implemented to solve maximization of a convex quadratic function over binary variables in parallel. The codes and some of the solved problems with solutions are available at [81, 82] and [3]. It has been adapted to solve basic problems in statistics and geometry [46].

General Inequalities for Arrangements and Oriented Matroids (1991–98)

In [36] we proved that in every arrangement of n hyperplanes in R^d the mean number of facets of a k-face is less than $2k$ for $k = 1, \ldots, d$. (For simple arrangements, the result can be obtained from Zaslavski's formula for the face number f_k of k-faces.) As a corollary, we immediately obtain a nice inequality for the face numbers: $f_k \leq \binom{d}{k} f_d$ for $k = 0, \ldots, d$. This result is extended to oriented matroids in [29]. The inequality is used in [37] for efficient enumeration of faces from the full-dimensional faces, and recently in [5] to obtain new results on acyclic orientations of a graph.

Connectivity in Oriented Matroids and Zonotopes (1993–98)
In [32], we proved the connectivities of various graphs associated with oriented matroids. We show that the 1-skeleton of every oriented matroid face poset of rank r is $2(r-1)$, while the 1-skeleton of the polar poset is r. One of the results implies that the graph (1-skeleton) of every d-dimensional zonotope is $2(d-1)$-connected. The results have been applied to a special case of oriented matroids arising from graphs in [5].

Antipodal Graphs and Oriented Matroids (1993)
In [30], we presented a graph theoretical study of oriented matroids. In particular, we gave a good characterization of oriented matroids of at most rank 3 in terms of tope graphs; a graph G is isomorphic to the tope graph of an oriented matroid of rank at most 3 if and only if it is planar, antipodal and isometrically embeddable in a hypercube. This result can be considered as an analogue of Steinitz' Theorem characterizing the graphs of 3-polytopes. The paper [30] presents elementary graph operations to construct recursively several classes of graphs arising from oriented matroids and generalizations. This enables us to construct all oriented matroids recursively, for example.

General Lower bounds for Convex Polytopes (1994)
In [27] we proved the best lower bounds for the number of vertices of a general convex d-polytope with any fixed number of k-faces. The lower bound for simple polytopes was proved by Barnette, but the general bound was not known for a while. Our bounds are sharp and attained by simplicial k-neighbourly polytopes.

Various Enumeration Algorithms (1992–97)
I have been working on developing efficient algorithms for various enumeration problems. The papers [34, 26, 23, 24, 20] present algorithms which uses techniques different from the reverse search.

Duality in Oriented Matroids (1989–90)
The papers [43, 41] study the duality of oriented matroids and more general structures. In particular, we characterize the sets $\mathcal{F}$ of sign vectors satisfying $(\mathcal{F})^{**} = \mathcal{F}$, where $*$ is the orthogonal operator for sign vectors. Various Farkas' type alternative theorems are proved for sign vector systems.

Oriented Matroid Deformation Theory (1982–88)
We developed the local deformation theory of OM. These deformations include perturbation [75], reverse perturbation and flipping operations [45], [63]. These deformations can be used to construct OMs with interesting properties, such as the non-Euclidean property.

Oriented Matroid Programming (1982)
In my Ph.D. thesis [75], I built a combinatorial foundation of LP in the abstract setting of oriented matroids, which became known as the oriented matroid programming (OMP) theory. This includes a simple inductive proof of the duality theorem and simple finite pivot algorithms, all of which are new even when they are restricted to the linear case. This foundation is based on the purely primal treatment of OMP as opposed to the primal-dual treatment of OMP taken by R. Bland in his pioneering work. This primal treatment provides most natural extensions of LP terminologies, and became "standard" as it is employed in the standard oriented matroid book by Björner-Las Vergnas-Sturmfels-White-Ziegler. (This is a joint work with J. Edmonds.)

Shellability of Oriented Matroid Polytopes (1982)
In [75], we proved that every oriented matroid polytope (dual to the Las Vergnas convex set) is shellable. The proof is by extending combinatorially the line shelling technique developed by Bruggesser and Mani. This shelling is known as the tope graph shelling. The Euler-Poincare

relation for an oriented matroid polytope is an immediate corollary. (This is a joint work with J. Edmonds)

Construction of non-Euclidean Oriented Matroids (1982)

This is one of the first results in my Ph.D. research [75]. This construction answers positively the question posed by R. Bland which says:

> Does there exists an oriented matroid that admits a directed cycle of affine points with respect to a fixed objective element?

When an oriented matroid is linear, such a cycle corresponds to a cyclic sequence of points in an affine d-space for which a linear function increases monotonically. Thus if such a cycle exists, the matroid must be nonlinear. I did succeed to construct an arrangement of 8 pseudo 2-spheres embedded in the three dimensional unit sphere, which yields an oriented matroid answering the question positively. Such an oriented matroid then became known as non-Euclidean. My example in fact gave birth to the theory of non-Euclidean oriented matroids. Many results on oriented matroids exhibiting a pathological behavior (relative to the linear case) often use some non-Euclidean OM. (A joint work with J. Edmonds and A. Mandel.)

LIST OF PUBLICATIONS

(1) Publication in Journals and in Books with Review Board

[1] K. Fukuda, S. Onn, and V. Rosta. An adaptive algorithm for vector partitioning. *Journal of Global Optimization*, 25:305–319, 2003.

[2] L. Finschi and K. Fukuda. Combinatorial generation of small point configurations and hyperplane arrangements. In B. Aronov and J. Pach, editors, *The Goodman-Pollack Festschrift*. Springer-Verlag, 2003. to appear.

[3] J.A. Ferrez, K. Fukuda, and Th. M. Liebling. Solving the fixed rank convex quadratic maximization in binary variables by a parallel zonotope construction algorithm. *European Journal of Operational Research*, 2003. to appear.

[4] L. Finschi and K. Fukuda. Generation of oriented matroids – a graph theoretical approach. *Discrete Comput. Geom.*, 27:117–136, 2002. ps file available from ftp://ftp.ifor.math.ethz.ch/pub/fukuda/reports/GenerationOfOMs001031.ps.gz.

[5] K. Fukuda, A. Prodon, and T. Sakuma. Notes on acyclic orientations and the shelling lemma. *Theoretical Computer Science*, 263:9–16, 2001. ps file available from ftp://ftp.ifor.math.ethz.ch/pub/fukuda/reports/acyclic980112.ps.gz.

[6] K. Fukuda, Th. M. Liebling, and C. Lütolf. Extended convex hull. *Computational Geometry*, 20:13–23, 2001.

[7] A. Deza, K. Fukuda, D. Pasechnik, and M. Sato. On the skeleton of the metric polytope. In J. Akiyama, M. Kano, and M. Urabe, editors, *Lecture Notes in Computer Science*, volume 2098, pages 125–136. Springer-Verlag, 2001.

[8] A. Bemporad, K. Fukuda, and F.D. Torrisi. Convexity recognition of the union of polyhedra. *Computational Geometry*, 18:141–154, 2001.

[9] E. Babson, L. Finschi, and K. Fukuda. Cocircuit graphs and efficient orientation reconstruction in oriented matroids. *Europ. J. Combinatorics*, 22(5):587–600, 2001. pdf file available from http://www.idealibrary.com/links/artid/eujc.2001.0481.

[10] K. Allemand, K. Fukuda, Th. M. Liebling, and E. Steiner. A polynomial case of unconstrained zero-one quadratic optimization. *Mathematical Programming, Ser. A*, 91:49–52, 2001.

[11] K. Fukuda and T. Terlaky. On the existence of a short admissible pivot sequence for feasibility and linear optimization problems. *Pure Mathematics and Applications, Mathematics of Optimization*, 10(4):431–447, 2000.

[12] R. Cordovil, K. Fukuda, and A. Guedes de Oliveira. On the cocircuit graph of an oriented matroid. *Discrete Comput. Geom.*, 24:257–265, 2000.

[13] B. Büeler, A. Enge, and K. Fukuda. Exact volume computation for convex polytopes: A practical study. In G. Kalai and G. M. Ziegler, editors, *Polytopes – Combinatorics and Computation*, DMV-Seminar 29, pages 131–154. Birkhäuser, 2000.

[14] A. Brüngger, A. Marzetta, K. Fukuda, and J. Nievergelt. The parallel search bench zram and its applications. *Annals of Operations Research*, 90:45–63, 1999. ps file available from ftp://ftp.ifor.math.ethz.ch/pub/fukuda/reports/zram970924.ps.gz.

[15] K. Fukuda, M. Namiki, and A. Tamura. EP theorems and linear complementarity problems. *Discrete Applied Mathematics*, 84:107–119, 1998.

[16] I.P.F. Da Silva and K. Fukuda. Isolating points by lines in the plane. *J. Geom.*, 62(1-2):48–65, 1998.

[17] D. Bremner, K. Fukuda, and A. Marzetta. Primal-dual methods for vertex and facet enumeration. *Discrete Comput. Geom.*, 20:333–357, 1998. ps file available from ftp://ftp.ifor.math.ethz.ch/pub/fukuda/reports.

[18] K. Fukuda and T. Terlaky. Criss-cross methods: A fresh view on pivot algorithms. *Mathematical Programming*, 79:369–395, 1997.

[19] K. Fukuda, H.-J. Lüthi, and M. Namiki. The existence of a short sequence of admissible pivots to an optimal basis in LP and LCP. *Int. Trans. Opl. Res.*, 4:273–284, 1997.

[20] K. Fukuda, Th. M. Liebling, and F. Margot. Analysis of backtrack algorithms for listing all vertices and all faces of a convex polyhedron. *Computational Geometry*, 8:1–12, 1997. ps file available from ftp://ftp.ifor.math.ethz.ch/pub/fukuda/reports/optvert9610.ps.gz.

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[22] D. Avis and K. Fukuda. Reverse search for enumeration. *Discrete Applied Mathematics*, 65:21–46, 1996.

[23] K. Fukuda and M. Namiki. Finding all common bases in two matroids. *Discrete Applied Mathematics*, 56:231–243, 1995.

[24] K. Fukuda and V. Rosta. Combinatorial face enumeration in convex polytopes. *Computational Geometry*, 4:191–198, 1994.

[25] K. Fukuda and M. Namiki. On extremal behaviors of murty's least index method. *Mathematical Programming*, 64:365–370, 1994.

[26] K. Fukuda and T. Matsui. Finding all the perfect matchings in bipartite graphs. *Appl. Math. Lett.*, 7(1):15–18, 1994.

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[28] G. Ceder, G.D. Garbulsky, D. Avis, and K. Fukuda. Ground states of a ternary fcc lattice model with nearest and next-nearest neighbor interactions. *Physical Review B*, 49(1):1–7, 1994. pdf file available from http://burgaz.mit.edu/papers/date.html.

[29] K. Fukuda, A. Tamura, and T. Tokuyama. A theorem on the average number of subfaces in arrangements and oriented matroids. *Geometricae Dedicata*, 47:129–142, 1993.

[30] K. Fukuda and K. Handa. Antipodal graphs and oriented matroids. *Discrete Mathematics*, 111:245–256, 1993.

[31] M. Deza, K. Fukuda, and M. Laurent. The inequicut cone. *Discrete Mathematics*, 119:21–48, 1993.

[32] R. Cordovil and K. Fukuda. Oriented matroids and combinatorial manifolds. *Europ. J. Combinatorics*, 14:9–15, 1993.

[33] K. Fukuda and T. Terlaky. Linear complementarity and oriented matroids. *Journal of the Operations Research Society of Japan*, 35:45–61, 1992.

[34] K. Fukuda and T. Matsui. Finding all minimum cost perfect matchings in bipartite graphs. *Networks*, 22:461–468, 1992.

[35] D. Avis and K. Fukuda. A pivoting algorithm for convex hulls and vertex enumeration of arrangements and polyhedra. *Discrete Comput. Geom.*, 8:295–313, 1992.

[36] K. Fukuda, S. Saito, A. Tamura, and T. Tokuyama. Bounding the number of k-faces in arrangements of hyperplanes. *Discrete Applied Mathematics*, 31:151–165, 1991.

[37] K. Fukuda, S. Saito, and A. Tamura. Combinatorial face enumeration in arrangements and oriented matroids. *Discrete Applied Mathematics*, 31:141–149, 1991.

[38] K. Fukuda and T. Matsui. On the finiteness of the criss-cross method. *European Journal of Operational Research*, 52:119–124, 1991.

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(4) Books, Lecture Notes and Expository Articles

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(5) Software

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PRESENTATIONS IN RECENT YEARS

- "From the Zonotope Contstruction to the Minkowski Addition of Convex Polytopes," 4th International Conference on Frontiers in Global Optimization, Santorini, June 12, 2003.
- "A parallel implementation of an arrangement construction algorithm," Invited talk, DIMACS workshop on Implementation of Geometric Algorithms, Rutgers University, December 2002.
- "Recent advances in polyhedral computation," Invited talk, FOCM workshop on Optimization, University of Minnesota, Minneapolis, August 2002.

- “Towards the limit of exhaustive search,” Invited talk, Latsis Symposium 2001 on Combinatorial Optimization, EPFL, Lausanne, November 2001.
- “Recent progress in polyhedral computation,” Dagstuhl Seminar on Integration of Algebra and Geometry Software Systems, Dagstuhl, Germany, October 2001.
- “Enumeration complexity and geometric computation,” Optimization Seminar, Advances Optimization Laboratory, McMaster University, Hamilton, Canada, Dec. 4, 2000.
- “Mysteries in linear programming,” Department of Mathematics, University of Calgary, Calgary, Canada November 30, 2000.
- “Vertex and facet enumeration for convex polytopes,” Computer Science Seminar, University of Calgary, Calgary, Canada November 29, 2000.
- “Extended Convex Hull,” Algorithm Seminar, School of Computer Science, McGill University, Montreal, Canada, September 6, 2000.
- “Cocircuit Graphs and Efficient Orientation Reconstruction in Oriented Matroids,” Klee - Grünbaum Geometry Festival, Ein Gev, Sea of Galilee, Israel, April 9 - 16, 2000.
- “Every cubical zonotope is uniquely determined by its dual graph,” Workshop on Lattices, Polytopes and Tilings, Mathematisches Forschungsinstitut, Oberwolfach, Germany, Feb. 27 – Mar. 4, 2000.
- “Linear programming techniques for polyhedral computation,” Invited Talk, Berliner Algorithmen Tag, TU-Berlin, Germany, February 18, 2000.
- “Cocicuit graphs and orientation reconstructions in oriented matroids,” Geometrie Combinatoires, CIRM, France, November 8–12, 1999.
- “Orientation reconstruction problems in arrangements and oriented matroids,” Computational Geometry, Dagstuhl Seminar, Germany, March 7 – 13, 1999.
- “On the existence of a short admissible pivot sequence for feasibility and linear optimization problems,” Workshop on Applied and Computational Geometry, Mathematisches Forschungsinstitut, Oberwolfach, Germany, Jan. 28 – Feb. 6, 1999.
- “Enumeration complexity and geometric combinatorics,” Invited Talk, International Conference on Combinatorial Methods in Mathematics, University of Porto, Portugal, July 9, 1998.
- “Acyclic orientations and the shelling lemma,” Invited Talk, Department of Mathematics, University of Porto, Portugal, July 14, 1998.
- “Vertex enumeration for convex polytopes – algorithms and open problems,” Invited Talk, Mathematical Institute of Hungarian Academic of Sciences, Budapest, Hungary, March 12, 1998.
- “Acyclic orientations, totally cyclic orientations and the shelling lemma,” Invited Talk, Eotvos Lorand University, Budapest, Hungary, March 11, 1998.

TEACHING

- “Data Structures and Algorithms,” Undergraduate Course, COMP-251B, School of Computer Science, McGill University, Winter 2003.

- “Information Structures I,” Graduate Course, COMP-610A, School of Computer Science, McGill University, Fall 2002.
- “Polyhedral Computation,” Graduate Course, M306-760B, School of Computer Science, McGill University, Winter 2002.
- “Chapitres choisis d’algorithmique,” (with Th.M. Liebling and A. Prodon), École Polytechnique Fédérale de Lausanne, Lausanne, Winter 2000.
- “Discrete Geometry,” Department of Computer Science (with J. Richter-Gebert), ETH Zurich, Winter 2000.
- “Computational Combinatorics,” Department of Mathematics, ETH Zurich, Spring-Summer 1999.
- “Optimierungstechniken,” Department of Mathematics (with H.-J. Lüthi), ETH Zurich, Fall-Winter 1998, 1999 and 2000.
- “Colloquium in Combinatorics, Geometric Algorithms and Optimization,” Graduate Seminar (with H.-J. Lüthi, J. Richter-Gebert and E. Welzl), ETH Zurich, Spring-Summer 1999.
- “Colloquium in Combinatorics, Geometric Algorithms and Optimization,” Graduate Seminar (with H.-J. Lüthi, J. Richter-Gebert and E. Welzl), ETH Zurich, Fall-Winter 1998.
- “Colloquium in Operations Research,” Graduate Seminar (with H.-J. Lüthi, J. Richter-Gebert and E. Welzl), ETH Zurich, Spring-Summer 1998.
- “Joint Colloquium in Operations Research and Algorithms – Geometry – Combinatorics,” Graduate Seminar, ETH Zurich, Spring 1997.
- “Méthodes et Applications sur Ordinateur Parallèles,” Cours postgrade, CAPA, École Polytechnique Fédérale de Lausanne, Lausanne, 1997.
- “A Constructive Approach to Polyhedral Geometry and Mathematical Programming,” Graduate Lecture in Mathematics, Department of Mathematics, ETH Zurich, Fall 1995 - Winter 1996.
- “Constructive LP Theory,” Graduate Seminar in Operations Research, Institute for Operations Research, Department of Mathematics, ETH Zurich, Spring 1995.
- “LP, LCP and Oriented Matroids,” Cours postgrade en Recherche Opérationnelle, École Polytechnique Fédérale de Lausanne, Lausanne, and Université Joseph Fourier, Grenoble, January 1995.
- “Linear Algebra,” Graduate School of Systems Management, University of Tsukuba, Tokyo, Spring 1994.
- “Calculus,” Graduate School of Systems Management, University of Tsukuba, Tokyo, Spring1994.
- “NP easy and LP theory,” Cours postgrade en Recherche Opérationnelle, École Polytechnique Fédérale de Lausanne, Lausanne, May1994 (with Jack Edmonds).
- “Algorithms and Data Structures,” Graduate School of Systems Management, University of Tsukuba, Tokyo, 1990-1993.
- “Projects in Mathematical Sciences,” Graduate School of Systems Management, University of Tsukuba, Tokyo, 1989-1993.

- "Systems Management Seminar," Graduate School of Systems Management, University of Tsukuba, Tokyo, 1989-1993.
- "Analysis for Global Environment," Graduate School of Systems Management, University of Tsukuba, Tokyo, 1989-1991.
- "Mathematica and its Applications," Graduate School of Systems Management, University of Tsukuba, Tokyo, 1992-1993.
- "Applications of Advanced Softwares," Graduate School of Systems Management, University of Tsukuba, Tokyo, spring 1993.
- "Networks and Combinatorial Optimization," Graduate School of Systems Management, University of Tsukuba, Tokyo, winter 1991, 1992, 1993.
- "Discrete Geometry," Department of Information Sciences, Tokyo Institute of Technology, Tokyo, fall 1992.
- "Matroids, Oriented Matroids and Computational Geometry," Cours postgrade en Recherche Opérationnelle, École Polytechnique Fédérale de Lausanne, Lausanne, and Université Joseph Fourier, Grenoble, fall 1993.
- "Fundamental Methods in Mathematical Sciences," Graduate School of Systems Management, University of Tsukuba, Tokyo, 1989-1992.
- "Graphs and Combinatorics," Graduate School of Systems Management, University of Tsukuba, Tokyo, winter 1990.
- "Data Structures," Graduate School of Systems Management, University of Tsukuba, Tokyo, winter 1990.
- "Linear Algebra," Department of Information Sciences, Tokyo Institute of Technology, Tokyo, spring of 1982-1988.
- "Graph Theory," Department of Information Sciences, Tokyo Institute of Technology, Tokyo, fall of 1987–88.
- "Research Projects in Mathematical Sciences," Department of Information Sciences, Tokyo Institute of Technology, Tokyo, fall of 1982–1988.
- "Linear Programming," Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Canada, spring 1981.

STUDENTS

Ph.D.

- Lukas Finschi, A graph theoretical approach for reconstruction and generation of oriented matroids, Ph.D. Thesis, Department of Mathematics, ETH Zurich, (2001).
- Christine Lütolf, Modeling and optimizing energy production, Ph.D. Thesis (advisor), Dept. of Mathematics, EPFL, (2001).
- Artur Andrzejak, On k-sets and their generalizations, Ph.D. Thesis (advisor), Dept. of Computer Sci, ETHZ, (1999).

- Ambros Marzetta, ZRAM: A Library of Parallel Search Algorithms and Its Use in Enumeration and Combinatorial Optimization, Ph.D. Thesis (advisor), Dept. of Computer Sci, ETHZ, (1998).
- Antoine Deza, Cut and metric polytopes, Ph.D. Thesis, University of Paris Sud (1995) and Ph. D. Thesis, Dept. of Information Sciences, Tokyo Institute of Technology, Tokyo, Japan (1996).
- Makoto Namiki, Combinatorial pivot algorithms for LCP, Ph.D. Thesis, Dept. of Information Sciences, Tokyo Institute of Technology, Tokyo, Japan (1996), currently an assistant professor at University of Tokyo.
- Keiichi Handa, Oriented matroids and related structures, Ph.D. Thesis, Dept. of Mathematical Science, Keio University, Yokohama, Japan(1993), currently a researcher at Systems & Software Engineering Lab, Tohsiba Corporation.
- Tomomi Matsui, Structure of Combinatorial Polyhedra, Ph.D. Thesis, Dept. of Information Sciences, Tokyo Institute of Technology, Tokyo, Japan (1991), currently an associate professor at University of Tokyo.
- Akihisa Tamura, Local deformations in oriented matroids, Ph.D. Thesis, Dept. of Information Sciences, Tokyo Institute of Technology, Tokyo, Japan (1989), currently an associate professor at Kyoto University, Kyoto.

Graduate Students

- Stefano Picozzi, Doctoral Program, Department of Mathematics, EPF Lausanne.
- Tallman Nkgau, Doctoral Program, School of Computer Science, McGill University, Montreal.
- Chris Wu, Master's Program, School of Computer Science, McGill University, Montreal.
- Jeff X. C. Hu, Master's Program, School of Computer Science, McGill University, Montreal.

Recent Research Projects

- K. Fukuda and V. Rosta. Computation of Halfspace and Regression Depths, NSERC, Canada, September 2002–.
- K. Fukuda. Polyhedral Computation, NSERC, Canada, April 2002–March 2006.
- K. Fukuda, S. Picozzi and Th.M. Liebling. Research Project on Redundancy Removal in Convex Polyhedra and Its Applications to Optimization and Computational Geometry, Swiss National Foundation, Switzerland, May 2003– 2004.
- K. Fukuda. Research Project on Polyhedral Geometry, Enumeration and Computational Complexity, Swiss National Foundation, Switzerland, April 2000–March 2002.
- D. Avis and K. Fukuda. The complexity of vertex enumeration and convex hull computation. Research in progress, McGill University and ETHZ, 1995–present.
- K. Fukuda, H.-J. Lüthi, and M. Namiki. Combinatorial pivot algorithms for LP and LCP. ETHZ and University of Tokyo, 1995.

- L. Finschi, K. Fukuda, H.-J. Lüthi, and M. Morari. Convex quadratic programming with few discrete variables. Research project, ETHZ, 1999.

- K. Fukuda, T.M. Liebling (EPFL) H.-J. Lüthi (ETHZ) and M. Vetterli (EPFL). ETHZ-EPFL joint research project on Optimization and Geometric Computation. Research in progress, ETHZ and EPFL, 1995–2001.

  - K. Fukuda, T.M. Liebling and C. Lütolf. Extended Convex Hull. EPFL, 1999.
  - K. Fukuda, B. Gärtner and T. Herrmann. Exact LP Solver. ETHZ, 2000–2001.
  - A. Bemporad, K. Fukuda and F.D. Torrisi. Convexity Recognition and Computation of the Union of Polytopes. ETHZ, 1999–2001.
  - A. Andrzejak, K. Fukuda and E. Welzl. Enumeration and complexity of k-sets and k-cells. ETHZ, 1998–1999.
  - L. Finschi, K. Fukuda and H.-J. Lüthi. Computational Combinatorics in Linear Subspaces. ETHZ, 1997–2001.
  - K. Fukuda, G. Heche, T.M. Liebling and A. Prodon. Enumeration and optimization of acyclic orientations. EPFL, 1997–1999.
  - J.-A. Ferrez, K. Fukuda and T.M. Liebling. Parallel algorithms for computing the diameter of a graph. EPFL, 1996–1998.
  - A. Andrzejak, K. Fukuda, T.M. Liebling and E. Welzl. Visualization tools for the k-set problem. ETHZ and EPFL, 1998.
  - K. Allemand, K. Fukuda, T.M. Liebling and A. Prodon. The unconstrained quadratic zero one programming. EPFL, 1998–2001.

    B. Büeler, A. Enge and K. Fukuda. Comparing exact volume computation methods for d-dimensional convex polytopes. IFOR, ETHZ, 1995–1998.