Algebraic Combinatorics

An International Conference
in Honor of
Eiichi Bannai's 60th Birthday

Supported by
Kyushu University COE Program
Graduate School of Information Sciences, Tohoku University

June 26 - June 30, 2006

Contents

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Eiichi Bannai (Fukuoka, Japan)
Andries Brouwer (Eindhoven, Netherlands)
Michel-Marie Deza (Paris, France)
Koichiro Harada (Columbus, USA)
Alexander A. Ivanov (London, UK)
Mikhail Klin (Beer Sheva, Israel)
Jack H. Koolen (Pohang, Korea)
Neil J. A. Sloane (AT&T Shannon Labs, USA)
Patrick Solé (Paris, France)
Paul Terwilliger (Madison, USA)

SPEAKERS AND TALK SCHEDULE

Abdukhalikov, Kanat	Thu	11:50	Kim, Jon-Lark	Mon	16:00
Amarra, Maria Carmen V.	Wed	10:20	Klin, Mikhail	Thu	10:20
Bachoc, Christine	Tue	14:10	Koolen, Jack	Mon	10:00
Bannai, Eiichi	Thu	16:20	Makhnev, Alexandre A.	Mon	15:40
Bannai, Etsuko	Fri	11:20	Manickam, N.	Tue	12:00
Brouwer, Andries	Mon	11:10	Martin, William J.	Mon	14:00
Cerzo, Diana	Mon	14:20	Oda, Fumihito	Fri	15:00
Choi, Sul-young	Fri	14:20	Ozeki, Michio	Wed	10:40
dela Cruz, Romar B.	Wed	11:40	Sali, Attila	Wed	11:20
Curtin, Brian	Fri	15:20	Sekiguchi, Jiro	Tue	15:40
van Dam, Edwin	Tue	11:20	Shen, Hao	Tue	16:00
Deza, Michel	Thu	15:10	Shinohara, Masashi	Fri	11:40
Evdokimov, Sergei	Mon	17:00	Shiromoto, Keisuke	Fri	10:20
Feng, Rongquan	Tue	15:20	Sloane, Neil J. A.	Wed	09:10
Fujisaki, Tatsuya	Fri	14:00	Solé, Patrick	Fri	09:10
Giudici, Michael	Mon	16:40	Song, Sung Y.	Thu	11:30
Harada, Koichiro	Thu	14:00	Suetake, Chihiro	Tue	16:40
Hiraki, Akira	Mon	15:20	Tamura, Hiroki	Tue	17:00
Hoshino, Ayumu	Tue	10:20	Tanabe, Kenichiro	Tue	10:40
Huang, Tayuan	Tue	11:40	Tanaka, Hajime	Fri	10:40
Ikuta, Takuya	Fri	15:40	Terwilliger, Paul	Tue	09:10
Ivanov, A. A.	Thu	09:10	Weng, Chih-wen	Mon	14:40

List of Registered Participants

Abdukhalikov, Kanat (Kyushu University, Japan)
Akiyama, Kenji (Fukuoka University, Japan)
Amarra, Maria Carmen V. (University of the Philippines, Philippines)
Bachoc, Christine (Université Bordeaux, France)
Balmaceda, Jose Maria (University of the Philippines, Philippines)
Bannai, Eiichi (Kyushu University, Japan)
Bannai, Etsuko (Kyushu University, Japan)
Betty, Rowena Alma (University of the Philippines, Philippines)
Brouwer, Andries (Eindhoven University of Technology, The Netherlands)
Cerzo, Diana (International Christian University, Japan)
Cheng, Shun-Jen (National Taiwan University, Taiwan)
Choi, Sul-young (Le Moyne College, USA)
dela Cruz, Romar (University of the Philippines, Philippines)
Curtin, Brian (University of South Florida, USA)
van Dam, Edwin (Tilburg University, The Netherlands)
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Evdokimov, Sergei (Petersburg Department of Steklov Institute of Mathematics, Russia)
Feng, Rongquan (Peking University, China)
Fujisaki, Tatsuya (Kyushu University, Japan)
Giudici, Michael (The University of Western Australia, Australia)
Hanaki, Akihide (Shinshu University, Japan)
Harada, Koichiro (The Ohio State University, USA)
Harada, Masaaki (Yamagata University, Japan)
Hiraki, Akira (Osaka Kyoiku University, Japan)
Hiramine, Yutaka (Kumamoto University, Japan)
Hirasaka, Mitsugu (Pusan National University, Korea)
Hoshino, Ayumu (Sophia University, Japan)
Hosoya, Rie (International Christian University, Japan)
Huang, Tayuan (National Chiao-Tung University, Taiwan)
Ikuta, Takuya (Kobe Gakuin University, Japan)
Ishikawa, Masao (Tottori University, Japan)
Ito, Tatsuro (Kanazawa University, Japan)
Ivanov, Alexander A. (Imperial College, UK)
Iwasaki, Shiro (Hitotsubashi University, Japan)
Jurišić, Aleksandar (IMFM, Slovenia)
Kaneko, Masanobu (Kyushu University, Japan)
Ke, Wen-Fong (National Cheng Kung University, Taiwan)
Kido, Hiroaki (Kyushu University, Japan)
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Koolen, Jack (POSTECH, Korea)
Koshitani, Shigeo (Chiba University, Japan)
Lang, Michael (Bradley University, USA)
Makhnev, Alexander (The Ural Branch of the Russian Academy of Sciences, Russia)

Manickam, Nachimuthu (DePauw University, USA)
Manickam, Arul (DePauw University, USA)
Marrero, Osvaldo (Villanova University, USA)
Martin, William J. (Worcester Polytechnic Institute, USA)
Miao, Ying (University of Tsukuba, Japan)
Miezaki, Tsuyoshi (Kyushu University, Japan)
Miyamoto, Izumi (University of Yamanashi, Japan)
Miyamoto, Masahiko (University of Tsukuba, Japan)
Mizukawa, Hiroshi (National Defense Academy in Japan, Japan)
Munemasa, Akihiro (Tohoku University, Japan)
Nakagawa, Nobuo (Kinki University, Japan)
Nakashima, Yasuhiro (Tohoku University, Japan)
Nozaki, Hiroshi (Kyushu University, Japan)
Nozawa, Sohei (Chiba University, Japan)
Oda, Fumihito (Toyama National College of Technology, Japan)
Okada, Soichi (Nagoya University, Japan)
Oura, Manabu (Kochi University, Japan)
Ozeki, Michio (Yamagata University, Japan)
Sali, Attila (Alfréd Rényi Institute of Mathematics, Hungary)
Sasaki, Hiroki (Shinshu University, Japan)
Sawabe, Masato (Chiba University, Japan)
Sekiguchi, Jiro (Tokyo University of Agriculture and Technology, Japan)
Shen, Hao (Shanghai Jiao Tong University, China)
Shigezumi, Junichi (Kyushu University, Japan)
Shimabukuro, Osamu (Fukushima National College of Technology, Japan)
Shimakura, Hiroki (Hokkaido University, Japan)
Shinohara, Masashi (Kyushu University, Japan)
Shiromoto, Keisuke (Aichi Prefectural University, Japan)
Sloane, Neil J. A. (AT&T, USA)
Solé, Patrick (CNRS, France)
Song, Sung Yell (Iowa State University, USA)
Suetake, Chihiro (Oita University, Japan)
Suprijanto, Djoko (Kyushu University, Japan)
Suzuki, Hiroshi (International Christian University, Japan)
Tagami, Makoto (Kanazawa University, Japan)
Tagami, Yuki (Tohoku University, Japan)
Takegahara, Yugen (Muroran Institute of Technology, Japan)
Tamura, Hiroki (Tohoku University, Japan)
Tanabe, Kenichiro (Hokkaido University, Japan)
Tanaka, Hajime (Tohoku University, Japan)
Tanaka, Yasuhiko (Oita University, Japan)
Taniguchi, Tetsuji (Kyushu University, Japan)
Taya, Hisao (Tohoku University, Japan)
Terwilliger, Paul (University of Wisconsin, Madison, USA)
Tokushige, Norihide (Ryukyu University, Japan)
Tomiyama, Masato (Ishikawa National College of Technology, Japan)
Wada, Tomoyuki (Tokyo University of Agriculture and Technology, Japan)
Watanabe, Toshihiro (Gifu University, Japan)
Weng, Chih-wen (National Chiao-Tung University, Taiwan)

Yamada, Hiromichi (Hitotsubashi University, Japan)
Yamaki, Hiroyoshi (Japan)
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Yokoyama, Kazuhiro (Rikkyo University, Japan)
Yoshiara, Satoshi (Tokyo Woman's Christian University, Japan)
Yoshida, Tomoyuki (Hokkaido University, Japan)

Part I

General Information

Announcements

1. **Information Desk Hours and Contact**

   Information Desk will open only during the daytime 9:00 am – 5:00 pm. During the after hours, you may call the organizing committee on emergency situation at:

   E-mail: munemasa@math.is.tohoku.ac.jp
   Mobile phone: 080-3187-9603 (Akihiro Munemasa)

   (Also you may send general inquiries to the above address.)

2. **Conference Venue**

   All talks and presentations will be held in Sendai International Center (Hagi Conference Hall). Local information including maps and transportation from/to the conference center, that are not listed in this booklet, can be obtained at the conference registration desk.

3. **Directions to Excursion**

   There will be an excursion to a cherry farm in the afternoon of Wednesday, June 28. Registered participants are requested to pay a fee of 4,000 yen at the information desk. If you have not arranged with pre-registration but you wish to join, then contact the information desk.

4. **Directions to the Conference Banquet**

   There will be a conference banquet on Thursday, June 29 at Sendai Excel Hotel Tokyu. Registered participants are requested to pay a fee of 5,000 yen (3,000 yen for students) at the information desk. If you have not arranged with pre-registration but you wish to join, then please sign up and pay the fee at the front desk by Tuesday, June 27.

5. **Internet Service**

   There will be two Windows PC's and a Mac connected to the internet near the information desk during the conference hours.

6. **Group Photo**

   Thursday 12:15 PM in front of the Conference Center.

Part II

Program

Timetable

June 26 (MON)		June 27 (TUE)		June 28 (WED)	
09:30-09:50	*Registration*	09:10-10:00	**P. Terwilliger**	09:10-10:00	**N. J. A. Sloane**
09:50-10:00	*Opening*	10:00-10:20	*Break*	10:00-10:20	*Break*
10:00-10:50	**J. Koolen**	10:20-10:40	A. Hoshino	10:20-10:40	M. C. V. Amarra
10:50-11:10	*Break*	10:40-11:00	K. Tanabe	10:40-11:00	M. Ozeki
11:10-12:00	**A. Brouwer**	11:00-11:20	*Break*	11:00-11:20	*Break*
12:00-14:00	*Lunch Break*	11:20-11:40	E. van Dam	11:20-11:40	A. Sali
14:00-14:20	W. J. Martin	11:40-12:00	T. Huang	11:40-12:00	R. B. dela Cruz
14:20-14:40	D. Cerzo	12:00-12:20	N. Manickam		*Excursion*
14:40-15:00	C.-W. Weng	12:20-14:10	*Lunch Break*		
15:00-15:20	*Break*	14:10-15:00	**C. Bachoc**		
15:20-15:40	A. Hiraki	15:00-15:20	*Break*		
15:40-16:00	A. A. Makhnev	15:20-15:40	R. Feng		
16:00-16:20	J.-L. Kim	15:40-16:00	J. Sekiguchi		
16:20-16:40	*Break*	16:00-16:20	H. Shen		
16:40-17:00	M. Giudici	16:20-16:40	*Break*		
17:00-17:20	S. Evdokimov	16:40-17:00	C. Suetake		
		17:00-17:20	H. Tamura		

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June 29 (THU)		**June 30 (FRI)**	
09:10-10:00	**A. A. Ivanov**	09:10-10:00	**P. Solé**
10:00-10:20	*Break*	10:00-10:20	*Break*
10:20-11:10	**M. Klin**	10:20-10:40	K. Shiromoto
11:10-11:30	*Break*	10:40-11:00	H. Tanaka
11:30-11:50	S. Y. Song	11:00-11:20	*Break*
11:50-12:10	K. Abdukhalikov	11:20-11:40	Et. Bannai
12:10-14:00	*Group Photo/Lunch*	11:40-12:00	M. Shinohara
14:00-14:50	**K. Harada**	12:00-14:00	*Lunch Break*
14:50-15:10	*Break*	14:00-14:20	T. Fujisaki
15:10-16:00	**M. Deza**	14:20-14:40	S.-Y. Choi
16:00-16:20	*Break*	14:40-15:00	*Break*
16:20-17:10	**Ei. Bannai**	15:00-15:20	F. Oda
18:00-	*Conference Dinner*	15:20-15:40	B. Curtin
		15:40-16:00	T. Ikuta

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Monday, June 26, 2006

Hagi Conference Hall, Sendai International Center
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Morning Session

Time	Speaker	Lecture Title
09:30 - 09:50		*Registration*
09:50 - 10:00		*Opening*
10:00 - 10:50	**Jack Koolen**	On a Conjecture of Bannai and Ito
10:50 - 11:10		*Break*
11:10 - 12:00	**Andries Brouwer**	Connectivity of Distance-Regular Graphs
12:00 - 14:00		*Lunch Break*

Afternoon Session on Monday

Time	Speaker	Lecture Title
14:00 - 14:20	**William J. Martin**	Imprimitive Cometric Association Schemes
14:20 - 14:40	**Diana Cerzo**	On Imprimitive Q-Polynomial Schemes of Exceptional Type
14:40 - 15:00	**Chih-wen Weng**	Triangle-Free Distance-Regular Graphs
15:00 - 15:20		*Break*
15:20 - 15:40	**Akira Hiraki**	A Characterization of the Odd Graphs and the Doubled Odd Graphs With a Few of Their Intersection Numbers
15:40 - 16:00	**Alexandre A. Makhnev**	On Distance-Regular Graphs and Their Automorphisms
16:00 - 16:20	**Jon-Lark Kim**	Small Weight Codewords in LDPC Codes Defined by (Dual) Classical Generalized Quadrangles
16:20 - 16:40		*Break*
16:40 - 17:00	**Michael Giudici**	Transitive Decompositions of Graphs
17:00 - 17:20	**Sergei Evdokimov**	Normal Cyclotomic Schemes Over a Finite Commutative Ring

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Tuesday, June 27, 2006

Hagi Conference Hall, Sendai International Center

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Morning Session

Time	Speaker	Lecture Title
09:10 - 10:00	**Paul Terwilliger**	The q-Tetrahedron Algebra
10:00 - 10:20		*Break*
10:20 - 10:40	**Ayumu Hoshino**	Polyhedral Realizations of Crystal Bases for Quantum Algebras
10:40 - 11:00	**Kenichiro Tanabe**	The Fixed Point Subalgebra of the Vertex Operator Algebra Associated to the Leech Lattice by an Automorphism of Order Three
11:00 - 11:20		*Break*
11:20 - 11:40	**Edwin van Dam**	Equidistant Latin Hypercube Designs
11:40 - 12:00	**Tayuan Huang**	Error-Correcting Pooling Designs Associated With Finite Geometries and Association Schemes
12:00 - 12:20	**N. Manickam**	Distribution Invariants of Association Schemes
12:20 - 14:10		*Lunch Break*

Afternoon Session on Tuesday

Time	Speaker	Lecture Title
14:10 - 15:00	**Christine Bachoc**	Upper Bounds for the Kissing Number From Semi-Definite Programming
15:00 - 15:20		*Break*
15:20 - 15:40	**Rongquan Feng**	On the Ranks of Bent Functions
15:40 - 16:00	**Jiro Sekiguchi**	An Analogy Between a Real Field and Finite Prime Fields on Six-Line Arrangements on a Projective Plane
16:00 - 16:20	**Hao Shen**	Embeddings of Resolvable Group Divisible Designs
16:20 - 16:40		*Break*
16:40 - 17:00	**Chihiro Suetake**	A Contraction of Divisible Designs
17:00 - 17:20	**Hiroki Tamura**	Some Constructions of Almost D-Optimal Designs

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Wednesday, June 28, 2006

Hagi Conference Hall, Sendai International Center

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Morning Session

Time	Speaker	Lecture Title
09:10 - 10:00	**Neil J. A. Sloane**	Gleason's Theorem on Self-Dual Codes and Its Generalizations
10:00 - 10:20		*Break*
10:20 - 10:40	**Maria Carmen V. Amarra**	$(1-u)$-Cyclic Codes Over $\mathbb{F}_{p^k} + u\mathbb{F}_{p^k}$
10:40 - 11:00	**Michio Ozeki**	Complete Coset Weight Enumeration of a Dual Pair in Binary Codes
11:00 - 11:20		*Break*
11:20 - 11:40	**Attila Sali**	Codes That Achieve Minimum Distance in All Directions
11:40 - 12:00	**Romar B. dela Cruz**	Hilbert Series and Free Distance Bounds for Quaternary Convolutional Codes
		Excursion After Lunch

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Thursday, June 29, 2006

Hagi Conference Hall, Sendai International Center

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Morning Session

Time	Speaker	Lecture Title
09:10 - 10:00	**A.A. Ivanov**	Amalgams: A Machinery of the Modern Theory of Finite Groups
10:00 - 10:20		*Break*
10:20 - 11:10	**Mikhail Klin**	Computer Algebra Experimentation With Coherent Configurations and Association Schemes
11:10 - 11:30		*Break*
11:30 - 11:50	**Sung Y. Song**	Group-Case Primitive Commutative Association Schemes and Their Character Tables
11:50 - 12:10	**Kanat Abdukhalikov**	Association Schemes Related to Universally Optimal Configurations
12:10 - 14:00		**Group Photo**/*Lunch Break*

Afternoon Session on Thursday

Time	Speaker	Lecture Title
14:00 - 14:50	**Koichiro Harada**	Rediscovered Theorems
14:50 - 15:10		*Break*
15:10 - 16:00	**Michel Deza**	Elementary Elliptic (R, q)-Polycycles
16:00 - 16:20		*Break*
16:20 - 17:10	**Eiichi Bannai**	Title to be announced
18:00 -		*Conference Dinner*

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Friday, June 30, 2006

Hagi Conference Hall, Sendai International Center

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Morning Session

Time	Speaker	Lecture Title
09:10 - 10:00	**Patrick Solé**	Double Circulant Codes From Two Class Association Schemes
10:00 - 10:20		*Break*
10:20 - 10:40	**Keisuke Shiromoto**	Designs From Subcode Supports of Linear Codes
10:40 - 11:00	**Hajime Tanaka**	A New Proof of the Assmus-Mattson Theorem Based on the Terwilliger Algebra
11:00 - 11:20		*Break*
11:20 - 11:40	**Etsuko Bannai**	New Examples of Euclidean Tight 4-Designs
11:40 - 12:00	**Masashi Shinohara**	On Three–Distance Sets in the Three–Dimensional Euclidean Space
12:00 - 14:00		*Lunch Break*

Afternoon Session on Friday

Time	Speaker	Lecture Title
14:00 - 14:20	**Tatsuya Fujisaki**	Trees and Spanning Trees in m-Uniform Hypergraphs
14:20 - 14:40	**Sul-young Choi**	Antimiddles of Trees
14:40 - 15:00		*Break*
15:00 - 15:20	**Fumihito Oda**	A Center of the Grothendieck Ring Green Functor
15:20 - 15:40	**Brian Curtin**	Isomorphisms and Homomorphisms of Graphs
15:40 - 16:00	**Takuya Ikuta**	Some Spin Models of Index 4 and Potts Models

Part III

Abstracts

Plenary Talks

Upper Bounds for the Kissing Number From Semi-Definite Programming

Christine Bachoc

This is a common work with Frank Vallentin. Using harmonic analysis on the unit sphere for a subgroup of the orthogonal group stabilizing a point, we work out a semidefinite program whose solution gives an upper bound for the kissing number (and more generally for spherical codes). Preliminary computations indicate that we should improve some known upper bounds of small dimensions. Our method is inspired by the recent work of A. Schrijver concerning binary codes.

Title to be announced

Eiichi Bannai

Kyushu University, Japan

Connectivity of Distance-Regular Graphs

Andries Brouwer

Elementary Elliptic (R, q)-Polycycles

Michel Deza and Mathieu Dutour

A (R, q)*-polycycle* is, roughly, a plane graph, whose faces, besides some disjoint *holes*, are i-gons, $i \in R$, and whose vertices, outside of holes, are q-valent. Such polycycle is called *elliptic*, *parabolic* or *hyperbolic* if $\frac{1}{q} + \frac{1}{r} - \frac{1}{2}$ (where $r = max_{i \in R} i$) is positive, zero or negative, respectively.

In elliptic case, we list all *elementary* (R, q)-polycycles, i.e. such that any (R, q)-polycycle is uniquely decomposed into agglomeration of elementary (R, q)-polycycles.

Rediscovered Theorems

Koichiro Harada

The classification of all simple groups of finite order was declared to be complete early in 1980's. It did not mean, however, that all relevant papers had actually been published at the time. One important paper had not been published for more than ten year after its announcement when Aschbaher and Smith took up the work of doing it from scratch in the latter half of 1990's. Their work was completed in 2004, thus completing the classification of all finite simple groups. Recently, a group of people (Aschbacher, Lyons, Smith, and Solomon) have been rechecking if indeed all relevant papers, minor or major, have been published. They discovered several missing papers. To my surprise, one of them is mine: 1) Finite groups having a component of type $\hat{M}_{22}$. Roughly speaking what I claimed was that there is no simple groups having an involution z such that the centralizer of z is isomorphic to the double cover of M_{22} or of $Aut(M_{22})$. I remember that I wrote such a paper and searched for it in my file. I found several typed copies of it. The paper was written in the late 1970's. At the Santa Cruz AMS Summer School for Group Theory held in 1979, it was reported that the Schur multiplier of M_{22} is a cyclic group of order 12, but not of order 6 as was believed previously. I must have put off the publication of my result on the double cover of M_{22} until the issue settled. Then, it was all forgotten and the copies began accumulating dust. This 'rediscovered theorem' will now be written jointly with Solomon in which the quadruple cover of M_{22} will also be treated. Aschbacher, Lyons, Smith, and Solomon found other 'rediscovered theorems'. Those are: 2) Aschbacher, M., Standard components of alternating type centralized by a 4-group. 3) Egawa, Y., Standard components of type $O_8(2)$. 4) Goldschmidt, D., On the 2-exponent of a finite group. These four rediscovered theorems will briefly be discussed in my talk.

Amalgams: A Machinery of the Modern Theory of Finite Groups

A.A. Ivanov

Traditionally finite groups are studied either as automorphism groups of certain geometric configurations or as abstract groups in terms of generators and relations. The amalgam method is a *symbiosis* of these two approaches. I would like to report on the progress in the project to establish the existence and uniqueness of the Monster group adopting the Monster amalgam as the first principle. The Monster group M is the largest among the exceptional (sporadic) finite simple groups. The Monster is particularly famous due to its connection with modular forms and vertex operator algebras. The Monster amalgam $\mathcal{M}$ is formed by a triple of subgroups in M, one of which is the involution centralizer isomorphic to $2_+^{1+24}.Co_1$. Here Co_1 is the automorphism group of the Leech lattice Λ modulo $\{\pm 1\}$-scalar transformations and 2_+^{1+24} is an extension of $\Lambda/2\Lambda$ by a centre of order 2. The main stages of the project is to (1) axiomatise the Monster amalgam $\mathcal{M}$; (2) prove that subject to the axioms $\mathcal{M}$ exists and unique; (3) define M as the largest group which contains $\mathcal{M}$ and which is generated by the elements of $\mathcal{M}$; (4) through analysing of the coset geometry associated with the pair $(M, \mathcal{M})$ prove that M is the Monster as we know it that is a finite simple group of a very impressive order. The ultimate goal of the project is to produce a vertex-operator algebra free construction of the Moonshine module for the Monster.

Computer Algebra Experimentation With Coherent Configurations and Association Schemes

Mikhail Klin

Ben-Gurion University of the Negev, Israel

On a Conjecture of Bannai and Ito

Jack Koolen

POSTECH

In the early 1980's Bannai and Ito conjectured that for given $k \geq 3$, there are finitley many distance-regular graphs with valency k. In a series of papers they showed that their conjecture is true for the class of bipartite distance-regular graphs. Also they showed that it is true for valency 3 and 4. Using their work on valency 3, Biggs, Boshier and Shawe-Taylor classified the distance-regular graphs with valency 3.

In this talk I will discuss some recent progress on this conjecture.

Gleason's Theorem on Self-Dual Codes and Its Generalizations

Neil J. A. Sloane

AT&T Shannon Labs, Florham Park, NJ, USA

One of the most remarkable theorems in coding theory is Gleason's 1970 theorem about the weight enumerators of self-dual codes. In the past 36 years there have been hundreds of papers written about generalizations and applications of this theorem to different types of codes, always on a case-by-case basis. In this talk I will state the theorem and then describe the far-reaching generalization that Gabriele Nebe, Eric Rains and I have developed which includes all the earlier generalizations at once. The full proof has just appeared in our book "Self-Dual Codes and Invariant Theory" (Springer, 2006).

Double Circulant Codes From Two Class Association Schemes

Patrick Solé

Two class association schemes consist of either strongly regular graphs (SRG) or doubly regular tournaments (DRT). We construct self-dual codes from the adjacency matrices of these schemes. This generalizes the construction of Pless ternary Symmetry codes, Karlin binary Double Circulant codes, Calderbank and Sloane quaternary double circulant codes, and Gaborit Quadratic Double Circulant codes (QDC). As new examples SRG's give 9 (resp. 29) new Type I (resp. Type II) $[72, 36, 12]$ codes. We construct a $[200, 100, 12]$ Type II code invariant under the Higman-Sims group, a $[200, 100, 16]$ Type II code invariant under the Hall-Janko group, and more generally self-dual binary codes attached to rank three groups. This is joint work with Steven Dougherty and Jon-Lark Kim.

Key Words: Self-dual code, 2-class association scheme, strongly regular graph, rank three groups, doubly regular tournament.

The q-Tetrahedron Algebra

Tatsuro Ito and Paul Terwilliger

We discuss the q-tetrahedron algebra from an algebraic and combinatorial point of view. We will show how the q-tetrahedron algebra is a q-analog of the three-point sl_2 loop algebra. We will discuss how the q-tetrahedron algebra is related to Leonard pairs and tridiagonal pairs. For any distance-regular graph that has classical parameters and formally self dual, we display an action of the q-tetrahedron algebra on the standard module. We discuss how this action is related to the subconstituent algebra.

Contributed Talks

Association Schemes Related to Universally Optimal Configurations

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In [3] two association schemes were considered and it was conjectured that these schemes determine universally optimal configurations in $\mathbb{R}^{10}$ and $\mathbb{R}^{14}$. It is known that these schemes are uniquely determined by there parameters [1].

The scheme on 40 points is a 4 class association scheme with automorphism group $2^4 : S_5$ (split extension). The stabilizer of a point is isomorphic to $2.S_4$ (nonsplit extension). The scheme generates a configuration of 40 points on unit sphere in $\mathbb{R}^{10}$. Rescaling these vectors we suppose that they lie on a sphere of radius 6. Then they generate integral isodual lattice Q_{10} [4] with automorphism group $2^{10} : S_6$. This lattice can be obtained by construction A from binary quadratic residue [10,5,4] code.

The scheme on 64 points is a 3 class association scheme with automorphism group $4^3 : (2 \times L_3(2))$, where $2 \times L_3(2)$ is the stabilizer of a point. The scheme generates a configuration of 64 vectors on a sphere of radius 7 in $\mathbb{R}^{14}$. These vectors generate integral lattice with automorphism group $2^{14} : (2^3 : L_3(2))$. The lattice can be obtained by construction A from binary shortened projective [14,4,7] code.

The latter scheme has a following generalization. Let C be a shortened $\mathbb{Z}_4$-Kerdock code [5] of length $2^m - 1$, m odd. It has 4^m codewords and nonzero codewords have Lee weights $2^m - 2^{(m-1)/2}$, 2^m and $2^m + 2^{(m-1)/2}$. Define an abelian 3 class association scheme on these codewords such that two nonequal codewords x and y are in the relations R_1, R_2 and R_3 if $x - y$ has Lee weight $2^m - 2^{(m-1)/2}$, 2^m and $2^m + 2^{(m-1)/2}$ respectively. The scheme has automorphism group $4^m : Aut(C)$. Recall that $Aut(C) \cong 2 \times L_3(2)$ for $m = 3$ and $Aut(C) \cong 2 \times (\mathbb{F}^*_{2^m} : Aut(\mathbb{F}_{2^m}))$ for $m > 3$.

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$(1-u)$-Cyclic Codes Over $\mathbb{F}_{p^k} + u\mathbb{F}_{p^k}$

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Let p be prime and $k \in \mathbb{N}$, and R_k be the commutative ring $\mathbb{F}_{p^k} + u\mathbb{F}_{p^k}$, where $u^2 = 0$. A code $\mathcal{C}$ of length n is said to be $(1-u)$-cyclic if it is invariant under the map ν, where

$$\nu(c_0, c_1, \ldots, c_{n-1}) = ((1-u)c_{n-1}, c_0, \ldots, c_{n-2}).$$

It will be proved that the Gray image of a linear $(1-u)$-cyclic code over R of length n is a distance-invariant cyclic p-ary code. It will also be proved that if $(n, p) = 1$, then every p-ary code which is the Gray image of a linear cyclic code of length n over R is permutation-equivalent to a cyclic code.

New Examples of Euclidean Tight 4-Designs

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The concept of Euclidean design was defined by Neumaier and Seidel in 1988 as a generalization of spherical designs. Delsarte and Seidel proved the Fisher type lower bounds for the cardinality of a Euclidean $2e$-design and that of an antipodal Euclidean $(2e+1)$-design, and they gave definitions of Euclidean tight designs. They conjectured that only tight Euclidean tight designs are trivial ones such as regular simplices. Recently, Eiichi Bannai-Etsuko Bannai, Etsuko Bannai and Bajnok constructed interesting Euclidean tight designs. In this talk we consider Euclidean tight 4-designs supported by 2 concentric spheres. In this case tight 4-designs must have 2 layers and each of them must be strongly regular graphs.

In this talk we give new examples of Euclidean tight 4-designs in $\mathbb{R}^n$ for $n = 4,\ 5,$, 6 and 22. These examples have the structures of combinatorial tight 4-designs. The case $n = 22$ corresponds to the nontrivial combinatorial tight 4-designs which is proved to be the unique nontrivial one by Enomoto-Ito-Noda in 1979.

We give another example of Euclidean tight 4-design in $\mathbb{R}^6$. One of the layer of this example has the structure of Hamming scheme $H(2,3)$.

We also show that there is no more Euclidean tight 4-designs supported by 2 concentric spheres.

On Imprimitive Q-Polynomial Schemes of Exceptional Type

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In [1], it was shown that an imprimitive Q-polynomial scheme $\mathcal{X} = (X, \{R_i\}_{0 \le i \le d})$ is either dual bipartite, dual antipodal or of class 4 or 6. Moreover, the dual intersection arrays of the imprimitive schemes of class 4 and 6 are given, respectively, by

$$\iota^*(\mathcal{X}) = \left\{ \begin{array}{ccccc} * & 1 & c_2^* & m - b_3^* & 1 \\ 0 & 0 & a_2^* & 0 & m-1 \\ m & m-1 & 1 & b_3^* & * \end{array} \right\}$$

where $a_2^* \neq 0$, and

$$\iota^*(\mathcal{X}) = \left\{ \begin{array}{ccccccc} * & 1 & c_2^* & c_3^* & 1 & c_5^* & m \\ 0 & 0 & a_4^* + a_5^* & 0 & a_4^* & a_5^* & 0 \\ m & m-1 & 1 & b_3^* & b_4^* & 1 & * \end{array} \right\}$$

where $a_2^* = a_4^* + a_5^* \neq 0$.

In this talk, we will show that the scheme of class 4 does not occur using the integrality conditions of the entries of the first eigenmatrix of $\mathcal{X}$. These integrality conditions arise from the fact that $\mathcal{X}$ has exactly one Q-polynomial ordering [2].

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Antimiddles of Trees

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Depending on the given criteria, a desirable location of a facility is either a central location or a location as far as possible, i.e., a middle or an antimiddle of a network. (The latter is also known as an obnoxious facility problem.) Due to their practical applications, various measures of middles and antimiddles using voting and planning procedures have been introduced, and algorithms to find them have gained much interest in a network environment. In this paper we restrict our focus to antimiddles of trees, and investigate the characteristics and relationship among them.

Hilbert Series and Free Distance Bounds for Quaternary Convolutional Codes

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A quaternary convolutional code is a $\mathbb{Z}_4(D)$-submodule of $\mathbb{Z}_4(D)^n$ where $\mathbb{Z}_4(D)$ is the ring of rational functions over $\mathbb{Z}_4$. Let $\mathcal{C}$ be a quaternary convolutional code with a basic polynomial generator matrix $G(D)$ satisfying the predictable degree property. We study the polynomial subcodes of $\mathcal{C}$ and show that these subcodes form a finitely-generated graded module over $\mathbb{Z}_4$. We derive the Hilbert series of $\mathcal{C}$ and use this to compute the rank of the polynomial subcodes. An upper bound for the Lee free distance of $\mathcal{C}$ is obtained in terms of the maximum possible minimum distances of the polynomial subcodes.

We also investigate the residue and torsion binary convolutional codes associated with $\mathcal{C}$. Another upper bound for the Lee free distance of $\mathcal{C}$ is proved using the Hamming free distance of the residue code. We also show how to construct a quaternary convolutional code from two binary convolutional codes in such a way that the two binary codes will be the residue and torsion codes of the quaternary code.

Isomorphisms and Homomorphisms of Graphs

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We discuss the use of the partition function (a statistical mechanical state-sum) to turn some problems concerning graphs into problems of algebraic geometry. We shall demonstrate this technique by showing how graph homomorphisms determine the isomorphism class of a given graph. We shall mention a couple other applications.

Fix a finite, undirected graph $G = (X, E)$ with no loops or multiple edges. We sketch the key steps of the argument showing that the isomorphism class of G is determined by graph homomorphisms into G. Let W be a matrix with rows and columns indexed by X. For each multidigraph $H = (V, E)$, the partition function of W by H is $Z^W(H) = \sum_\sigma \prod_{(u,v)\in E} W(\sigma(u), \sigma(v))$, where σ runs over all maps from V to X. It is known that if A is the adjacency matrix of G, then $Z^A(H)$ is equal to the number of graph homomorphisms from H into G. However, if Λ is the matrix with (x, y)-entry equal to a variable $\lambda_{x,y}$ indexed by the position, then $Z^\Lambda(H)$ is a polynomial. It turns out that the polynmials $Z^\Lambda(H)$ generate the ring of polynomial invariants for the symmetric group on X acting diagonally on the subscripts of the variables. Now an elementary argument gives that the common zeros of the polynomials $\{Z^\Lambda(H) - Z^A(H) \mid H \text{ is a multidigraph}\}$ is precisely the orbit of A under the diagonal action of this group on matrices with rows and columns indexed by X. It follows that the isomorphism class of G is determined by the values $Z^A(H)$, which count graph homomorphisms.

Equidistant Latin Hypercube Designs

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A Latin hypercube design of n points and dimension k consists of n points $X_i = (x_{i1}, ..., x_{ik})$, $i = 1, ..., n$, such that $\{x_{1j}, ..., x_{nj}\} = \{0, 1, ..., n-1\}$ for each j. We are interested in maximizing the minimal distance among the points of such a design, for a given number of points, and dimension. An obvious bound for the minimal distance is the average distance, which can be made explicit, and is the same for all Latin hypercube designs of a given number of points n and dimension k. Sometimes, the bound can be attained, and we obtain equidistant designs. We present results when this is the case, for the ℓ^1-distance and for the ℓ^2-distance. We also present results for the ℓ^∞-case, which is related to certain graph decompositions.

Normal Cyclotomic Schemes Over a Finite Commutative Ring

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Let R be a finite commutative ring and $\mathcal{C} = \mathrm{Cyc}(K, R)$ a cyclotomic scheme over R defined by a group $K \le R^\times$ where $R^\times$ is the multiplicative group of R. The scheme $\mathcal{C}$ is called *normal* if $\mathrm{Aut}(\mathcal{C}) \le A\Gamma L_1(R)$. We are interested in the criterion of normality for $\mathcal{C}$. The following statement reduces the general case to the local one.

Theorem 1. *Let $R = \prod_{i\in I} R_i$ and $\mathcal{C}_i = \mathrm{Cyc}(K_i, R_i)$ where $K_i = K \cap R_i^\times$. Then the scheme $\mathcal{C}$ is normal if and only if the scheme $\mathcal{C}_i$ is normal for all i.*

Now let the ring R be local. A group $K \le R^\times$ is called *pure* (resp. *quasipure*) if the equality $K + I = K$ where I is an ideal of R, implies that $I = 0$ (resp. $I \subset \mathrm{ann}(\mathrm{rad}(R))$). Denote by q the cardinality of the residue field of R.

Theorem 2. *If the scheme $\mathcal{C}$ is normal, then the group K is pure for $q > 2$ and quasipure for $q = 2$.*

For the Galois rings the above necessity condition is essentially sufficient.

Theorem 3. *Let R be a Galois ring other than a field. Then the scheme $\mathcal{C}$ is normal if and only if the group K is pure for $q > 2$ and quasipure for $q = 2$.*[1]

Let $R = \mathbb{F}$ be a field. If $K = \mathbb{F}^\times$, then it is easy to see that the scheme $\mathcal{C}$ is normal if and only if $q = 2, 3, 4$; otherwise, the following statement is true.

Theorem 4 (McConnel, 1963). *If $K < \mathbb{F}^\times$, then the scheme $\mathcal{C}$ is normal.*

With each cyclotomic scheme $\mathcal{C}$ over R we associate in a natural way certain Schur ring $\mathcal{A}$ over $R^\times$. The study of $\mathcal{A}$, on one hand, enables us to prove Theorem 3. On the other hand, we give a new short proof of Theorem 4 (and consequently of the Burnside theorem on groups of prime degree). This proof is completely based on the theory of Schur rings over a cyclic group recently developed by Leung-Man [2] and the authors [1].

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On the Ranks of Bent Functions*

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Let $\mathbb{F}_2$ be the finite field with 2 elements, and let $\mathbb{F}_2^n$ be the n-dimensional vector space over $\mathbb{F}_2$. Let k be an integer and $f : \mathbb{F}_2^k \to \mathbb{F}_2$ be a Boolean function. The incidence matrix A_f of f is defined to be the $2^k \times 2^k$ one whose columns and rows are indexed by elements of $\mathbb{F}_2^k$ and the (x, y)-th entry $A_f(x, y) = f(x + y)$ for all $x, y \in \mathbb{F}_2^k$. The *rank* of the Boolean function f, denoted by $rank(f)$, is defined to be the rank of its incidence matrix A_f over the field $\mathbb{F}_2$.

A map $f : \mathbb{F}_2^k \to \mathbb{F}_2$ is called a *bent function* if the Fourier coefficient

$$F(y) = 2^{-k/2} \sum_{x \in \mathbb{F}_2^k} (-1)^{f(x)+x\cdot y}$$

has constant magnitude 1 for all $y \in \mathbb{F}_2^k$. It is well-known that there exists a bent function from $\mathbb{F}_2^k$ to $\mathbb{F}_2$ if and only if $k = 2t$ is even. Two bent functions f and g from $\mathbb{F}_2^{2t}$ to $\mathbb{F}_2$ are equivalent if $g(x) = f(\sigma(x) + \beta) + \ell(x)$ for an automorphism $\sigma \in \mathrm{Aut}(\mathbb{F}_2^{2t}, +)$, an element $\beta \in \mathbb{F}_2^{2t}$ and an affine function ℓ from $\mathbb{F}_2^{2t}$ to $\mathbb{F}_2$.

It is very difficult to check whether two given bent functions are equivalent or not. In this talk, we show that the rank is an invariant under the equivalence relation among bent functions. So bent functions can be distinguished by calculating their ranks. Furthermore, Some upper and lower bounds of ranks of general bent functions, Maiorana-McFarland bent functions and Desarguesian partial spread bent functions are given. As a consequence, it is proved that almost every Desarguesian partial spread bent function is not equivalent to a Maiorana-McFarland one.

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Trees and Spanning Trees in m-Uniform Hypergraphs

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An m-uniform hypergraph (V, E) is defined by a finite set V and a set E of m-subset of V, where $m \geq 2$. Similarly to the graph theory, we can define tree and spanning tree. In my talk, I will show the following results:

1. For a set V, there exists a set E of m-subset of V forming a tree if and only if the size of V is equal to $k(m-1)+1$ for some positive integer k. In this case, the number of tree on V is equal to

$$|V|^{k-1}\frac{(k(m-1))!}{k!((m-1)!)^k}.$$

2. Let $A_1, A_2, \cdots, A_m$ be mutually disjoint (non-empty) sets satisfying $\sum_{i=1}^m |A_i| = k(m-1)+1$ for some positive integer k. Put $V = A_1 \cup A_2 \cup \cdots \cup A_m$ and $E = \{\{v_1, v_2, \cdots, v_m\} \mid v_i \in A_i\}$. A hypergraph (V, E) has a spanning tree if and only if $a_i = |A_i|$ is at most k for any i. In this case, the number of spanning tree of (V, E) is equal to

$$k^{m-2}\prod_{i=1}^{m} a_i^{b_i-1}\frac{\prod_{i=1}^m a_i!}{\prod_{i=1}^m b_i!}$$

where $b_i = k - a_i$.

Transitive Decompositions of Graphs

Michael Giudici

A *decomposition* of a graph is a partition of the arc set or edge set. Decompositions are especially interesting when the subgraphs induced by each part are pairwise isomorphic, and there has been much attention paid to determining when a given graph can be decomposed into copies of a certain subgraph, for example, into cycles or 1-factors. A *transitive decomposition* is a decomposition preserved by some group of automorphisms which acts transitively on the partition. Transitive decompositions of complete graphs into complete subgraphs are equivalent to line-transitive linear spaces. Moreover, the linear space is flag-transitive if and only if the group is arc-transitive. After discussing some of the other connections I will outline the recent classification with Alice Devillers, Cai Heng Li and Cheryl Praeger of transitive decompositions of Johnson graphs with an arc-transitive automorphism group. Amongst the examples found is a decomposition of $J(12, 4)$ into copies of a valency 8 graph with 165 vertices and automorphism group M_{11}.

A Characterization of the Odd Graphs and the Doubled Odd Graphs With a Few of Their Intersection Numbers

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We show several inequalities for intersection numbers of distance-regular graphs. An application of them we characterize the Odd graphs and the doubled Odd graphs by a few of their intersection numbers. In particular, we prove that the diameter d of a bipartite distance-regular graph of valency k and girth $2r + 2 \geq 6$ is bounded by $d \leq \left[\frac{k+2}{2}\right] r + 1$ if it is not the doubled Odd graph.

Polyhedral Realizations of Crystal Bases for Quantum Algebras

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The quantum algebra $U_q(\mathfrak{g})$, which is called *q-analogue* of the universal enveloping algebra for a symmetrizable Kac-Moody Lie algebra $\mathfrak{g}$. Kashiwara showed that the nilpotent part $U_q^-(\mathfrak{g})$ and the integrable $U_q(\mathfrak{g})$-module $V(\lambda)$ have the crystal bases. We can deal with the representation theory using combinatorial methods by the theory of crystal bases. Polyhedral realization of crystal bases, which is introduced by Nakashima and Zelevinsky, is one of the methods for explicitly describing the crystal base $B(\infty)$ of a $U_q^-(\mathfrak{g})$. We can describe a vector in the crystal base $B(\infty)$ as a lattice point of a certain convex polyhedron in an infinite $\mathbb{Z}$-lattice by this method. This method can be applied to the crystal bases $B(\lambda)$ of $V(\lambda)$ for symmetrizable Kac-Moody Lie algebras. But the explicit forms of the polyhedral realizations of crystal bases $B(\infty)$ and $B(\lambda)$ have only been given in the cases of arbitrary rank 2, A_n and $A_n^{(1)}$. In my talk, we will give the polyhedral realizations of crystal bases $B(\infty)$ and $B(\lambda)$ for all simple Lie algebras and some affine cases. Moreover, we will present the explicit formula of multiplicity of the tensor product of two integrable highest weight modules(Littlewood-Richardson number) using polyhedral realization method.

Error-Correcting Pooling Designs Associated With Finite Geometries and Association Schemes

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The notion of d-disjunct matrices was first introduced by Kautz and Singleton in 1964, and has been generalized to (s, l)-superimposed codes and designs by D'yachkov and Torney *et. al.* in 2002, and to $(s, l; e)$-*generalized cover free families* recently by Stinson. All these structures can be used in combinatorial group testing algorithms applicable to DNA library screening, and they are therefore called *pooling designs*.

As pointed out by D.-Z. Du that the structure of association schemes may play an important role in improving the performance of pooling designs, a few families of (s, l, e)- disjunct matrices defined over *Johnson graphs* and *Grassmann graphs* were previously considered. Following this way, error - correcting pooling designs based on incidence matrices associated with distance regular graphs over some finite geometries will be considered in this talk, including the *symplectic geometry* and the *attenuated spaces*. It then leads to the notion of *pooling spaces, i.e.*, ranked partially ordered sets with certain atomic intervals. Optimal error correcting capability for a few families of pooling designs derived from pooling spaces with intervals carrying the structure of projective geometries will be considered.

A decoding algorithm for pooling designs based on (s, l, e)- disjunct matrices will also be included in this talk. Moreover, we will show that (s, l, e)- disjunct matrices also provide a class of pooling designs over complexes, called *setwise group testing*, which fits the practical consideration better.

This is a joint work with Kaishun Wang and Chih-wen Weng.

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Some Spin Models of Index 4 and Potts Models

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A spin model (for link invariants) is a square matrix W with non-zero complex entries which satisfies certain axioms. F. Jaeger and K. Nomura are shown that ${}^tWW^{-1}$ is a permutation matrix (the order of this permutation matrix is called the "index" of W), and a general form was given for spin models of index 2. Moreover, new spin models, called non-symmetric Hadamard models, were constructed. K. Nomura and I determine the general form of non-symmetric spin models for any index m $(m \geq 3)$.

In this talk, we present the following new infinite spin models of non-symmetric spin models of index 4.

$$W = \begin{pmatrix} W_{11} & W_{12} \\ W_{21} & W_{22} \end{pmatrix}.$$

where,

$$W_{11} = W_{22} = \left(\begin{array}{cccc|cccc} 1 & 1 & 1 & 1 & \xi & -\xi & \xi & -\xi \\ 1 & 1 & 1 & 1 & -\xi & \xi & -\xi & \xi \\ 1 & 1 & 1 & 1 & \xi & -\xi & \xi & -\xi \\ 1 & 1 & 1 & 1 & -\xi & \xi & -\xi & \xi \\ \hline -\xi & \xi & -\xi & \xi & 1 & 1 & 1 & 1 \\ \xi & -\xi & \xi & -\xi & 1 & 1 & 1 & 1 \\ -\xi & \xi & -\xi & \xi & 1 & 1 & 1 & 1 \\ \xi & -\xi & \xi & -\xi & 1 & 1 & 1 & 1 \end{array}\right) \otimes A$$

$$W_{12} = \left(\begin{array}{cccc|cccc} 1 & \eta^3 & -1 & \eta & 1 & \eta & -1 & \eta^3 \\ \eta & 1 & \eta^3 & -1 & \eta^3 & 1 & \eta & -1 \\ -1 & \eta & 1 & \eta^3 & -1 & \eta^3 & 1 & \eta \\ \eta^3 & -1 & \eta & 1 & \eta & -1 & \eta^3 & 1 \\ \hline \eta & -1 & \eta^3 & 1 & 1 & \eta^3 & -1 & \eta \\ 1 & \eta & -1 & \eta^3 & \eta & 1 & \eta^3 & -1 \\ \eta^3 & 1 & \eta & -1 & -1 & \eta & 1 & \eta^3 \\ -1 & \eta^3 & 1 & \eta & \eta^3 & -1 & \eta & 1 \end{array}\right) \otimes \tau H$$

$$W_{21} = \left(\begin{array}{cccc|cccc} \eta & -1 & \eta^3 & 1 & 1 & \eta^3 & -1 & \eta \\ 1 & \eta & -1 & \eta^3 & \eta & 1 & \eta^3 & -1 \\ \eta^3 & 1 & \eta & -1 & -1 & \eta & 1 & \eta^3 \\ -1 & \eta^3 & 1 & \eta & \eta^3 & -1 & \eta & 1 \\ \hline \eta^3 & -1 & \eta & 1 & \eta & -1 & \eta^3 & 1 \\ 1 & \eta^3 & -1 & \eta & 1 & \eta & -1 & \eta^3 \\ \eta & 1 & \eta^3 & -1 & \eta^3 & 1 & \eta & -1 \\ -1 & \eta & 1 & \eta^3 & -1 & \eta^3 & 1 & \eta \end{array}\right) \otimes \tau H$$

A is a Potts model ($A = -u^3 + u^{-1}(J - I)$, $D = -u^2 - u^{-2}$). H is a symmetric Hadamard matrix. $\eta = \exp(2\pi\sqrt{-1}/4)$, $\xi^2 = -\eta$, $\tau^4 = -\eta\xi$.

Small Weight Codewords in LDPC Codes Defined by (Dual) Classical Generalized Quadrangles

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The concept of low-density parity check (LDPC) codes was introduced by Gallager (1962) and it was shown by MacKay and Neal (1998) that these codes perform well under iterative probabilistic decoding. A binary *LDPC code* C, in its broader sense, is a linear block code defined by a sparse parity check matrix H, i.e., H has much fewer 1s than 0s. When the columns of H have a constant weight ρ and the rows of H also have a constant weight γ, we call C an $(\rho,\ \gamma)$*-regular LDPC code.*

Vontobel and Tanner [2] considered the LDPC codes generated by generalized polygons, focusing on generalized quadrangles. We find lower bounds on the minimum distance and characterize codewords of small weight in LDPC codes defined by (dual) classical generalized quadrangles. We analyze the geometry of the non-singular parabolic quadric in $PG(4, q)$ to find information about the low-density parity check codes defined by $Q(4, q)$, $\mathcal{W}(q)$ and $\mathcal{H}(3, q^2)$. For $\mathcal{W}(q)$ and $\mathcal{H}(3, q^2)$, we are able to describe small weight codewords geometrically. For $\mathcal{Q}(4, q)$, q odd, and for $\mathcal{H}(4, q^2)^D$, we improve the best known lower bounds on the minimum distance. Similar results are also presented for the LDPC codes $\mathrm{LU}(3, q)$ defined by Kim, *et. al.* [1].

[1] J.-L. Kim, U. Peled, I. Perepelitsa, V. Pless and S. Friedland, Explicit construction of families of LDPC codes with no 4-cycles, IEEE Trans. Inform. Theory, Vol. 50 (2004) pp. 2378–2388.
[2] P. O. Vontobel and R M. Tanner, Construction of codes based on finite generalized quadrangles for iterative decoding, Proceedings of 2001 IEEE Intern. Symp. Inform. Theory, (2001) p. 223.

On Distance-Regular Graphs and Their Automorphisms

Makhnev Alexandre A.

Let Γ be a distance-regular graph of diameter d with v vertices. Then for basic matrices $A_0, ..., A_d$ and for matrices $E_0, ..., E_d$ of the orthogonal projections onto the eigenspaces $W_0, W_1, ..., W_d$ ($W_0 = \langle \mathbf{1} \rangle$) from $\mathbf{C}^v$ we have

$$A_i = \sum_{j=0}^{d} P_{ij} E_j \text{ and } E_i = v^{-1} \sum_{j=0}^{d} Q_{ij} A_j,$$

where P and Q are first and second eigenmatrices of an association scheme corresponding Γ.

The image of E_i is the ith eigenspace W_i, and so E_i affords the character χ_i of the automorphism group G of Γ. For $g \in G$ we have

$$\chi_i(g) = v^{-1} \sum_{j=0}^{d} Q_{ij} \alpha_j(g),$$

where $\alpha_j(g)$ is the numbers of vertices x of Γ such that $d(x, x^g) = j$.

Let Γ be a distance-regular graph with intersection array $\{60, 45, 8; 1, 12, 50\}$ and $g \in \mathrm{Aut}(\Gamma)$. Then

$$P = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 60 & 14 & 0 & -10 \\ 225 & -5 & -5 & 15 \\ 36 & -10 & 4 & -6 \end{pmatrix}, \; Q = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 45 & 21/2 & -1 & -25/2 \\ 207 & 0 & -23/5 & 23 \\ 69 & -23/2 & 23/5 & -23/2 \end{pmatrix}.$$

So $\chi_2(g) = (45\alpha_0(g) - \alpha_2(g) + 5\alpha_3(g)/70$, $\chi_3(g) = (5\alpha_0(g) + \alpha_2(g))/20 - 23/2$.

Theorem 1 (Gavrilyuk A.L., Makhnev A.A.). *Let Γ be a distance-regular graph with intersection array $\{60, 45, 8; 1, 12, 50\}$, g be an element of prime order $p \geq 5$ of $\mathrm{Aut}(\Gamma)$ and $\Omega = \mathrm{Fix}(g)$. Then one of the following holds.*

(1) *Ω is empty graph and $p = 7$ or 23.*

(2) *$p = 5$ and either $\Omega = \{a, b\}$ and $d(a, b) = 3$, or $|\Omega| = 7$ and $\Gamma_3(a) \cap \Omega$ is 6-clique for some vertex $a \in \Omega$.*

Corollary 1. *Let Γ be a distance-regular graph with intersection array $\{60, 45, 8; 1, 12, 50\}$. Then Γ is not distance-transitive.*

Let Γ be a distance-regular graph with intersection array $\{8, 7, 5; 1, 1, 4\}$ and $g \in \mathrm{Aut}(\Gamma)$. Then

$$Q = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 54 & 81/4 & 27/28 & -27/7 \\ 50 & -25/4 & -25/4 & 5 \\ 30 & -15 & 30/7 & -15/7 \end{pmatrix}.$$

So $\chi_2(g) = (5\alpha_0(g) + \alpha_3(g))/12 - 25/4$, $\chi_3(g) = (7\alpha_0(g) + 3\alpha_2(g) + 2\alpha_3(g))/21 - 15$.

Theorem 2 (Belousov I.N., Makhnev A.A.). *Let Γ be a distance-regular graph with intersection array $\{8, 7, 5; 1, 1, 4\}$, g be an element of prime order of $\mathrm{Aut}(\Gamma)$ and $\Omega = \mathrm{Fix}(g)$. Then one of the following holds.*

(1) *Ω is empty graph and $p = 3$ or 5.*

(2) $\Omega = \{a, b\}$ *is* 2*-clique and* $p = 7$.

(3) $p = 2$ *and*

(i) $d(a, b) = 3$ *for any two vertices* $a, b \in \Omega$ *and* $|\Omega| = 3, 5, 7, 9, 11, 13$*, or*

(ii) Ω *contains two vertices of valency* 4*, eight vertices of valency* 2 *and one or three vertices of valency* 0*, or*

(iii) Ω *contains gexagon and one isolated vertex.*

Corollary 2. *Let* Γ *be a distance-regular graph with intersection array* $\{8, 7, 5; 1, 1, 4\}$*. Then* Γ *is not vertex-transitive.*

Distribution Invariants of Association Schemes

N. Manickam

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The notion of distribution invariants was first introduced by Thomas Bier while attempting to answer certain questions in the algebra of real numbers. Later, along with Delserte, Bier generalized the definition of distribution invariants to any symmetric association schemes. In this talk, I will present the results proved so far on this topic, including the recent Ph.D. thesis work of Bhattacharya on this topic.

Imprimitive Cometric Association Schemes

William J. Martin[1] Mikhail Muzychuk[2] Jason Williford[1]

In contrast to the P-polynomial case, very few examples are currently known of cometric association schemes which are not also metric and many elementary questions about the parameters of cometric schemes remain unanswered.

In this talk, we survey the known examples of cometric association schemes and introduce some new examples. Dualizing the "extended bipartite double" construction for distance-regular graphs, we have constructed a new family of cometric schemes with four associate classes which are both Q-bipartite and Q-antipodal.

The focus of this talk is a "dismantlability" theorem: we prove that any Q-antipodal association scheme is dismantlable: the configuration induced on any subset of the the equivalence classes in the Q-antipodal imprimitivity system is again a cometric association scheme. We will finish with a number of examples and an application.

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A Center of the Grothendieck Ring Green Functor

Fumihito Oda and Tomoyuki Yoshida

It is well known that there exists an isomorphism of commutative rings between the evaluation $\zeta_A(\bullet)$ at the one point G-set $\bullet = G/G$ of the center ζ_A of a Green functor A for a finite group G over a commutative ring $\mathcal{O}$ and the center $Z(A(\Omega^2))$ of the evaluation $A(\Omega^2)$ at the G-set $\Omega^2 = \Omega \times \Omega$ of A, where $\Omega = \cup_{H \leq G} G/H$. If A is the fixed point functor $FP_{\mathcal{O}}$, then the above isomorphism induces an isomorphism between the center of $\mathcal{O}G$ and the center of the Hecke algebra $\mathrm{End}_{\mathcal{O}G}(\oplus_{H \leq G}(\mathrm{Ind}_H^G \mathcal{O}))$ defined by Yoshida. The Dress construction for a Green functor in terms of G-sets is as follows: let G^c denote the group G, on which G acts by conjugation. Then the Mackey functor A_{G^c} obtained from A by Dress construction has a natural structure of Green functor. In particular $A_{G^c}(\bullet)$ is a ring. If A is $FP_{\mathcal{O}}$, then the ring $A_{G^c}(\bullet)$ is the center $Z(\mathcal{O}G)$ of the group algebra $\mathcal{O}G$. Bouc showed that there exists a morphism Z_A of Green functors from the commutant $C(A, G^c)$ of A in A_{G^c} to ζ_A. This result provides in particular a natural ring homomorpism $Z_A(\bullet)$ from $C(A, G^c)(\bullet)$ to the center $\zeta_A(\bullet)$ of the category A-mod of left A-modues (Mackey functors). So, a natural problem is to study $\zeta_A(\bullet)$ for a Green functor A.

In Seattle conference in 1996, Yoshida pointed out that the center $\mathbb{C} \otimes Z(R_{\mathbb{C}}, G)$ of the span category of the Grothendieck ring Green functor $R_{\mathbb{C}}$ for G over the field $\mathbb{C}$ of the complex numbers is very similar to the Grothendieck algebra $\mathbb{C}R(D(\mathbb{C}G))$ of the Drinfeld double of the group algebra $\mathbb{C}G$. The purpose of this talk is to give an answer to the reason why $\mathbb{C} \otimes Z(R_{\mathbb{C}}, G)$ is similar to $\mathbb{C}R(D(\mathbb{C}G))$ and to the problem we mention above, for the Grothendieck ring Green functor R for G over $\mathbb{C}$.

Complete Coset Weight Enumeration of a Dual Pair in Binary Codes

Michio Ozeki

In this talk we treat the problem of the determination of complete coset weight enumeration for a given binary linear code. When the code is self-dual, we now have good tools such as invariant theory for finite groups and the theory of association scheme. In the case that the code in question is linear but not self-dual, the above tools can not help us much. We present a method to treat this problem in non self-dual codes. The idea is to treat not only the code C but the dual code $C^{\perp}$ of C. When the coset weight distributions of $C^{\perp}$ behave rather simply, we utilize this to obtain the coset weight distributions of C. The interaction between these two codes are interesting in some respects. We will explain our approach in the case of BCH codes and their duals, but the method will apply for a wide class of dual pairs such as Reed-Muller codes or others.

Codes That Achieve Minimum Distance in All Directions

Attila Sali and Klaus-Dieter Schewe

Existence of Armstrong instances of uniform key systems in relational databases give rise to the following problem. Let $\mathcal{C}$ be a q-ary code of length n with minimum distance k. Assume that for all possible k-subset of coordinates there exists a pair of codewords of minimum distance that differ in exactly of those coordinates. We consider q and k be given and investigate lower and upper bounds for n as function of q and k. The bounds we obtain are of the same order of magnitude as functions of k, but so far differ as functions of q. The lower bounds are given by semi-greedy constructions, the upper bounds follow from some combinatorial counting argument.

An Analogy Between a Real Field and Finite Prime Fields on Six-Line Arrangements on a Projective Plane

Jiro Sekiguchi

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A simple six-line arrangement is obtained by a system of six lines $L_1, L_2, \ldots, L_6$ with the conditions; (1) they are mutually different and (2) no three of them intersect at a point. We add the condition that (3) there is no conic tangent to all the lines. It is known that there are four kinds of simple six-line arrangements on a real projective plane (cf. B. Grünbaum, *Convex Polytopes*). Among the four kinds, one is characterized by the existence of a hexagon and one is characterized by the condition that the conic tangent to any five lines of the six lines does not intersect the remaining line.

The sixth symmetric group acts on the totality of simple six-line arrangements with conditions (1), (2), (3) as permutations among lines and it extends to the action of the Weyl group $W(E_6)$ of type E_6. There are six-line arrangements which are fixed by a subgroup of $W(E_6)$ isomorphic to a fifth symmetric group. It is shown in J. Sekiguchi and M. Yoshida, $W(E_6)$-action on the configuration space of 6 points of the real projective plane, *Kyushu J. Math.*, **51** (1997) that $W(E_6)$ acts transitively on the set of six-line arrangements fixed by a group isomorphic to a fifth symmetric group and that this is decomposed into four subsets by the sixth symmetric group action. These four sets are in a one to one correspondence with the four kinds of simple-six line arrangements mentioned above.

The purpose of this talk is to study what happens when we replace a real projective plane by a projective plane over a finite prime field. Let p be a prime integer, $\mathbf{F}_p$ the field consisting of p points and $\mathbf{P}^2(\mathbf{F}_p)$ the projective plane over $\mathbf{F}_p$. Let $L_1, L_2, \ldots, L_6$ be six lines on $\mathbf{P}^2(\mathbf{F}_p)$ with the conditions (1), (2), (3). Then we show that if 5 is quadratic residue mod p, there is a simple six-line arrangement on $\mathbf{P}^2(\mathbf{F}_p)$ fixed by a fifth symmetric group. Now assume that there is $n \in \mathbf{F}_p$ such that $n^2 \equiv 5\ (p)$. Our next result is that there is a six-line arrangement fixed by a fifth symmetric group such that the conic tangent to any five lines of the six lines does not intersect the remaining line if and only if $\pm 2n - 5$ is non-quadratic residue mod p.

It is well-known that for a prime p, 5 is quadratic residue mod p if and only if $p = 10k + 1$ or $p = 10k - 1$ for a positive integer k. My conjecture is that for a prime p, there is $n \in \mathbf{F}_p$ such that $n^2 \equiv 5\ (p)$ and there is no $m \in \mathbf{F}_p$ such that $m^2 \equiv 2n - 5\ (p)$, if and only if $p = 10k - 1$ for a positive integer k. I checked by direct computation that the conjecture is true for $p < 1000$.

Embeddings of Resolvable Group Divisible Designs

Hao Shen
(Joint work with Jun Shen)

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A group divisible design of order v and index λ, denoted by GD$(k, \lambda, m; v)$, is an ordered triple $(X, \mathcal{G}, \mathcal{B})$ where X is a v-set, $\mathcal{G}$ is a set of subsets (called groups) of X such that $\mathcal{G}$ partitions X and $|G| = m$ for each $G \in \mathcal{G}$, and $\mathcal{B}$ is a collection of subsets (called blocks) of X such that $|B| = k$ for each $B \in \mathcal{B}$, with the property that each pair of elements of X is contained either in a unique group or in λ blocks, but not both.

A GD$(k, \lambda, m; v)$ is called resolvable and denoted RGD$(k, \lambda, m; v)$ if its blocks can be partitioned into parallel classes, each of which forms a partition of X.

Let $(X_1, \mathcal{G}_1, \mathcal{B}_1)$ be an RGD$(k, \lambda, m; v)$, and $(X_2, \mathcal{G}_2, \mathcal{B}_2)$ be an RGD$(k, \lambda, m; u)$. If $X_1 \subset X_2$, $\mathcal{G}_1 \subset \mathcal{G}_2$ and each parallel class of $\mathcal{B}_1$ is a part of some parallel class of $\mathcal{B}_2$, then we say $(X_1, \mathcal{G}_1, \mathcal{B}_1)$ is embedded in $(X_2, \mathcal{G}_2, \mathcal{B}_2)$, or $(X_2, \mathcal{G}_2, \mathcal{B}_2)$ contains $(X_1, \mathcal{G}_1, \mathcal{B}_1)$ as a subdesign.

The embedding problem for resolvable group divisible designs has been studied extensively since 1987. In this talk, we will report our recent results which completely determine necessary and sufficient conditions for the embeddings of resolvable group divisible designs with block size 3 for any λ.

On Three–Distance Sets in the Three–Dimensional Euclidean Space

Masashi Shinohara

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A subset X in the d-dimensional Euclidean space $\mathbb{R}^d$ is called a k–distance set if there are exactly k distances between two distinct points in X. For two subsets in $\mathbb{R}^d$, we say that they are isomorphic if there exists a similar transformation from one to the other. An interesting problem on k–distance sets is to determine the largest possible cardinality of k–distance sets in $\mathbb{R}^d$. We denote this number by $g_d(k)$. For $k = 2$, the numbers $g_d(2)$ are known for $d \leq 8$. For $d = 2$, the numbers $g_2(k)$ are known for $k \leq 5$. However, for $d \geq 3$ and $k \geq 3$, even the smallest case $g_3(3)$ have not been determined. In this case, S. J. Einhorn–I. J. Schoenberg conjectured that the vertices of the regular icosahedron is the only 12-point three-distance set in $\mathbb{R}^3$. In this talk, we prove the uniqueness of 12-point three-distance sets in the two-dimensional sphere S^2 and prove the nonexistence of a 14-point three-distance set in $\mathbb{R}^3$.

Designs From Subcode Supports of Linear Codes

Thomas Britz and Keisuke Shiromoto*

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There are various methods that a linear code forms t-designs in coding theory and design theory. In particular, it is well-known that the set of supports for the codewords of same weight in a linear code with certain properties corresponds to the set of blocks in a t-design. For instance, the Assmus-Mattson theorem has given a substantial sufficient condition for that by using the Hamming weight enumerator. The number of researchers have constructed new t-designs from linear codes by using the theorem.

In this talk, we explain how to construct t-designs from subcodes of a linear code over a finite fields. We consider the *support* of a subcode as the union of supports for all codewords in the subcode And the *support weight* of a subcode is the size of that support. Then we give some conditions on a linear code such that the set of supports for all r-dimensional subcodes of same support weight in the code forms the set of blocks in a t-design. We first explain the conditions on the automorphism group of a linear code under the above situation. Next, we consider the *support weight enumerator* of a linear code which is a generalization of the Hamming weight enumerator. Then we prove an Assmus-Mattson type theorem for the subcodes support by concentrating on the enumerator. Using these results, we give some $\{3, 4, 5\}$-designs obtained from the subcodes support of linear codes over finite fields.

Group-Case Primitive Commutative Association Schemes and Their Character Tables

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Many infinite classes of primitive commutative association schemes come from finite transitive permutation groups. Examples include many classical groups acting on finite geometries. The character tables of some of these association schemes have been constructed by Bannai and his school since 1985. In this talk, we will collect all known examples of such commutative association schemes and calculation results of their character tables with some discussion of tools and methods employed in the calculation. In doing this, we will touch upon the work of many people including that of Bannai-Hao(Shen)-Song, Bannai-Kawanaka-Song, Bannai-Kwok, Bannai-Shen-Song-Wei, Bannai-Song, Bannai-Tanaka, and Fujisaki. We will also discuss some open problems and conjectures of Bannai related to the study of character tables and classification problems of group-case primitive commutative association schemes as time permits.

A Contraction of Divisible Designs

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Let $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ be a finite incidence structure ($v = |\mathcal{P}|,\ b = |\mathcal{B}|$).

First of all we give the definitions of several special cases of divisible designs. $\mathcal{D}$ is called an $(m, u, k, \lambda)-$*divisible design* and denoted by $\mathrm{DD}_\lambda[k, u; v]$ if the following two conditions are satisfied.

(i) The point set $\mathcal{P}$ is partitioned into m *point classes* $\mathcal{P}_1, \cdots, \mathcal{P}_m$ such that $|\mathcal{P}_1| = \cdots = |\mathcal{P}_m| = u$, where $m = \frac{v}{u}$ and the number $[p_1, p_2]$ of blocks containing any two distinct points $p_1, p_2 (\in \mathcal{P})$ satisfies

$$[p_1, p_2] = \begin{cases} \lambda & \text{if } p_1 \text{ and } p_2 \text{ are in distinct point classes,} \\ 0 & \text{otherwise.} \end{cases}$$

(ii) $|B| = k$ for every block $B \in \mathcal{B}$.

Let $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ be a $\mathrm{DD}_\lambda[k, u; v]$ and G a subgroup of $\mathrm{Aut}(\mathcal{D})$. Then G is said to be *class semiregular* if G leaves each point class invariant and each nontrivial element of G has no fixed pont on $\mathcal{P}$.

Let $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ be a $\mathrm{DD}_\lambda[k, u; v]$. If $|\mathcal{P}| = |\mathcal{B}|$, then $\mathcal{D}$ is called *square*.

Let $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ be a $\mathrm{DD}_\lambda[k, u; v]$. If the dual structure of $\mathcal{D}$ is also a $\mathrm{DD}_\lambda[k, u; v]$, then $\mathcal{D}$ is called *symmetric* and denoted by $\mathrm{SDD}_\lambda[k, u; v]$.

Let $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ be a $\mathrm{DD}_\lambda[k, u; v]$, $v = um$. By definition, $m \geq k$. If $m = k$, $\mathcal{D}$ is called a *transversal design* and denoted by $\mathrm{TD}_\lambda[k, u; v]$. If a $\mathrm{TD}_\lambda[k, u; v]$ is square, then $k = m = u\lambda, b = v = u^2\lambda$ and denoted by $\mathrm{TD}_\lambda[k; u]$. Furthermore, if $\mathrm{TD}_\lambda[k; u]$ is symmetric, then it is called a *symmetric transversal design* and denoted by $\mathrm{STD}_\lambda[k; u]$.

Let $\mathcal{D}$ be a $\mathrm{DD}_\lambda[k, u; v]$ and $\mathcal{D}'$ be a $\mathrm{DD}_{\lambda s}[\frac{\lambda(v-u)}{k-1}, \frac{u}{s}; \frac{v}{s}]$, where s divides u. Let O be the $s \times s$ zero matix. Then $\mathcal{D}'$ is said to be a *contraction* of $\mathcal{D}$, if there exist an incidence matrix $L' = ({l_{ij}}')$ of $\mathcal{D}'$ and a permutation matrix M_{ij} for any (i, j) with ${l_{ij}}' = 1$ such that $L = (L_{ij})$ is an incidence matrix of $\mathcal{D}$, where $L_{ij} = \begin{cases} O & \text{if } {l_{ij}}' = 0 \\ M_{ij} & \text{if } {l_{ij}}' = 1 \end{cases}$.

We prove the following three thorems.

Theorem 1. If an automorphism group G of a $\mathrm{DD}_\lambda[k, u; v]$ $\mathcal{D}$ of order s is class semiregular, then there exists a contraction $\mathrm{DD}_{\lambda s}[\frac{\lambda(v-u)}{k-1}, \frac{u}{s}; \frac{v}{s}]$ $\mathcal{D}'$ of $\mathcal{D}$.

Theorem 2. Any $\mathrm{STD}_2[12; 6]$ admits no nontrivial automorphism which leaves each point classes and each block classes invariant.

Theorem 3. Let $\mathcal{D} = (\mathcal{P}, \mathcal{B})$ be a $\mathrm{TD}_\lambda[k; u]$ with k odd and let p be a prime which divides the square free part of k. If an automorphism σ of $\mathcal{D}$ of order $q (\neq p)$ acts semiregularly on each point classes of $\mathcal{D}$, then $\mathrm{Ord}_q(p)$ is odd.

Some constructions of almost D-optimal designs

Hiroki Tamura

Ehlich block matrix of order $n \equiv 3 \pmod 4$ is a square $n \times n$ matrix with block structure whose diagonal entries are n, off-diagonal entries of diagonal blocks are 3, and the other entries are -1. I listed up candidates of Ehlich block matrix Y of order $n \leq 99$ satisfying $XX^T = X^TX = Y$ for some square design matrix $X \in \mathcal{X}_n$, where $\mathcal{X}_n$ is the set of all $n \times n$ matrices with entries ± 1. For some of them, the design matrices actually exist and some of the designs seem to be almost D-optimal. When the number of blocks is 4, we have many candidates but it seems difficult to construct them. I give some constructions of the design matrices of order $n = 27, 31, 39, 59$.

The Fixed Point Subalgebra of the Vertex Operator Algebra Associated to the Leech Lattice by an Automorphism of Order Three

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and

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We study the subalgebra of the lattice vertex operator algebra V_Λ consisting of the fixed points of an automorphism which is induced from an order 3 isometry of the Leech lattice Λ. We classify the simple modules for the subalgebra. The rationality and the C_2-cofiniteness are also established.

A New Proof of the Assmus-Mattson Theorem Based on the Terwilliger Algebra

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For simplicity, we only deal with binary Hamming schemes $H(D,2)$ throughout this talk. Let $\mathcal{T} = \mathcal{T}(\mathbf{0})$ denote the Terwilliger algebra with respect to the zero vector $\mathbf{0} \in \mathbb{F}_2^D$ and let W be any irreducible $\mathcal{T}$-module. For each non-empty subset $C \subseteq \mathbb{F}_2^D$, we introduce an *outer distribution B of C with respect to W* and the *dual degree s^* of C with respect to W*. When W is the (unique) irreducible $\mathcal{T}$-module of endpoint 0, they coincide with the outer distribution and the dual degree of C in the usual sense. We find that B has rank $s^* + 1$ and that each column of B is a linear combination of the first $s^* + 1$ columns of B. As an application, we use this fact to provide a new proof of the Assmus-Mattson theorem. These results are part of my ongoing project that extends Delsarte's theory based on the Terwilliger algebra and semidefinite programming.

Triangle-Free Distance-Regular Graphs

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Let Γ denote a distance-regular graph with $d \geq 3$. By a *parallelogram of length* 3, we mean a 4-tuple $xyzw$ consisting of vertices in Γ such that $\partial(x, y) = \partial(z, w) = 1$, $\partial(x, z) = 3$, and $\partial(x, w) = \partial(y, w) = \partial(y, z) = 2$, where ∂ denotes the path-length distance function. Assume Γ has intersection numbers $a_1 = 0$ and $a_2 \neq 0$. We prove the following (i), (ii) are equivalent. (i) Γ is Q-polynomial and contains no parallelograms of length 3; (ii) Γ has classical parameters (d, b, α, β). Furthermore, suppose (i), (ii) hold we show that each of $b(b+1)^2(b+2)/c_2$, $(b-2)(b-1)b(b+1)/(2+2b-c_2)$ is an integer and that $c_2 \leq b(b+1)$.

Keywords: Distance-regular graph, Q-polynomial, classical parameters.

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