The 2^{nd} International Coding Theory Seminar

India (online)

March 15th, 2024

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About

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Timetable

All times listed are in Indian Standard Time (GMT+5:30).

Time: March 15th, 2024

Participants Meeting ID: 693 457 4771

Participants Passcode: 2ICTSIndia

09:30-10:00	**Committee Discussion**	
10:15–10:30	**Inauguration**	Jon-Lark Kim
10:30–11:15	**Sudhir Ghorpade** IIT Bombay, India	Recent advances in projective Reed-Muller codes
11:15–11:30	**Discussion/Break**	
11:30–12:15	**Navin Kashyap** IISc Bangalore, India	Recent Progress on Reed-Muller Codes: An Overview
12:15–12:30	**Discussion/Break**	
12:30–13:15	**Pradeep Sarvepalli** IIT Madras, India	Almost 30 years of quantum coding theory: An incomplete review
13:15–13:30	**Discussion**	

List of Talks

Talk 1: Recent advances in projective Reed-Muller codes

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Biography

Sudhir R. Ghorpade earned his B.Sc. from University of Bombay in 1982, M.Sc. from IIT Bombay in 1984, and Ph.D. from Purdue University, USA, under the supervision of Prof. Shreeram S. Abhyankar, in 1989. Subsequently, he joined IIT Bombay, where he currently holds the position of Dr. K. V. Ramachandran Chair Professor in the Department of Mathematics. He has held visiting faculty positions in Denmark, France, Germany and USA, and has given numerous seminar/colloquium talks or presentations in conferences worldwide. His research interests include Algebraic Geometry, Coding Theory, Combinatorics, and Commutative Algebra. He received an AICTE Career Award for Young Teachers in 1998, Prof. S.C. Bhattacharya Award for Excellence in Pure Sciences from IIT Bombay in March 2014, and IIT Bombay Research Paper Award for 2011 as well as for 2022. He is a Fellow of the National Academy of Sciences since 2010 and a Fellow of the Indian National Science Academy since 2023. He serves on the editorial board of several journals including the IEEE Transactions on Information Theory, where he is an Associate Editor for Coding Theory since 2019. He was the President of the Indian Mathematical Society during April 2018–March 2019. Currently, he is the Head of the National Centre for Mathematics (India) and the Vice-President of the Indian Mathematics Consortium.

Abstract
Projective Reed-Muller codes are a natural variant of generalized Reed-Muller codes, and they were introduced by Lachaud (1986, 1991) and Sørensen (1991). Given a prime power q and integers d, m with $m \geq 1$ and $d \geq 0$, the corresponding projective Reed-Muller code $\mathrm{PRM}_q(d, m)$ is a q-ary linear code of length $p_m := q^m + q^{m-1} + \cdots + q + 1$. When $d < q$, the dimension of $\mathrm{PRM}_q(d, m)$ is $\binom{m+d}{d}$, which coincides with the dimension of the Reed-Muller code $\mathrm{RM}_q(d, m)$ of order d and length q^m. Questions about the minimum distance of $\mathrm{PRM}_q(d, m)$ led Tsfasman to make a conjecture about the maximum number of zeros that a homogeneous polynomial in $m + 1$ variables of degree d with coefficients in the finite field $\mathbb{F}_q$ can have in the projective space $\mathbb{P}^m(\mathbb{F}_q)$. This conjecture was proved by Serre (1991). Independently Sørensen determined the minimum distance of projective Reed-Muller codes $\mathrm{PRM}_q(d, m)$ of arbitrary order d. A characterization of minimum weight codewords of projective Reed-Muller codes was given by Ballet and Rolland (2014), building upon an earlier work of Rolland (2008). An alternative proof of Sørensen's formula

for the minimum distance of $\mathrm{PRM}_q(d,m)$, characterization of minimum weight codewords, and also an explicit formula for the number of minimum weight codewords of $\mathrm{PRM}_q(d,m)$ has been given recently in [13] (see also [30]). Various formulas for the dimension of $\mathrm{PRM}_q(d,m)$ are known, thanks to Sørensen (1991), Renteria and Tapia-Recillas (1997), Mercier and Rolland (1998), and Can, Joshua and Ravindra (2023); see also [13]. Automorphism groups of projective Reed-Muller code were determined by Berger (2002), thereby extending a seminal result of Berger and Charpin (1993) for Reed-Muller codes.

There has been much interest in the explicit determination of the generalized Hamming weights of projective Reed-Muller codes. A conjectural formula for $d_r\left(\mathrm{PRM}_q(d,m)\right)$ was proposed by Tsfasman and Boguslavsky (1997) in the case $d < q-1$ and $r \leq \binom{m+d}{d}$. Results of Serre (1991) and Boguslavsky (1997) showed that this holds in the affirmative when $r = 1$ and $r = 2$. Datta and Ghorpade (2015, 2017) showed that the conjecture of Tsfasman and Boguslavsky holds in the affirmative when $r \leq m+1$, but it is false, in general. A new conjecture was proposed in the case $d < q$ and $r \leq \binom{m+d-1}{d-1}$. This was proved by Beelen, Datta and Ghorpade (2018) when $r \leq \binom{m+2}{2}$. A "complete conjecture" valid for any $r \leq \binom{m+d}{d}$ was proposed by Beelen, Datta and Ghorpade (2022) and proved in several cases. A recent result of Singhal and Lin (2023) shows that this "complete conjecture" holds for all large enough q.

Working in a different direction, the weight distribution, and more generally, higher weight spectrum of projective Reed-Muller codes $\mathrm{PRM}_q(d,m)$ has been investigated by Johnsen and Verdure for small values of d and m, and this has close relations to the so called Betti numbers of these codes.

We will review these developments and outline some significant results and open problems.

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Talk 2: Recent Progress on Reed-Muller Codes: An Overview

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Biography

Navin Kashyap received a B.Tech. in Electrical Engineering from the Indian Institute of Technology, Bombay, an M.S. in Mathematics and a Ph.D. in Electrical Engineering: Systems from the University of Michigan, Ann Arbor. After a two-year postdoctoral stint at the University of California, San Diego, he joined the faculty of the Department of Mathematics and Statistics at Queen's University, Kingston, Ontario, Canada, where he remained till December 2010. Thereafter, he has been with the Department of Electrical Communication Engineering at the Indian Institute of Science, where he is currently a Professor. His research interests lie primarily in the application of combinatorial and probabilistic methods in information and coding theory. Prof. Kashyap is a recipient of the Swarnajayanti Fellowship awarded by the Department of Science and Technology, Government of India. He is at present an Associate Editor for the SIAM Journal on Discrete Mathematics, and for the Springer journal Cryptography and Communications.

Abstract

Reed-Muller (RM) codes are one of the oldest families of error-correcting codes, with numerous applications in coding theory, cryptography and theoretical computer science. They are named after David Muller, who introduced them in 1954, and Irving Reed who, also in 1954, gave an algorithm for decoding the code up to half its minimum distance. But, even after 70 years of their discovery, there is still much to learn about this beautiful family of codes. Indeed, there has been, of late, a renewed interest in binary RM codes that stems in part from the runaway success of the closely-related family of polar codes. Binary RM codes have also benefitted from the celebrated result of Kudekar et al. (2017) proving that these codes, under maximum a-posteriori probability (MAP) decoding, achieve the Shannon capacity of a binary erasure channel. This result has subsequently been extended to arbitrary binary-input symmetric memoryless (BMS) channels by Reeves and Pfister (2021) and Abbé and Sandon (2023). These works together constitute a major milestone in coding theory, as it is the first time that a completely explicit family of algebraic codes has been proved to achieve capacity over a broad class of memoryless channels.

In this talk, we give an overview of the recent progress made in our understanding of binary RM codes, including their capacity-achieving property mentioned above. We will specifically cover developments in three related aspects of binary RM codes: (1) their weight distributions; (2) their capacity-achieving property under MAP decoding; and (3) low-complexity decoding algorithms. It is indeed rather remarkable that, despite the simplicity of their construction, we do not yet have a good understanding of the weight distribution of this code family. For instance, it was only very recently (Sept. 2023) that the complete weight distribution of RM(9,4), a self-dual code of length 512, was computed by Markov and Borissov with the use of significant computational power. And, following the proof of the capacity-achieving performance of RM codes under MAP decoding, the hunt is on for efficient decoders that can yield provably good performance at moderate blocklengths.

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Talk 3: Almost 30 years of quantum coding theory: An incomplete review

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Biography

Pradeep Kiran Sarvepalli received the B.Tech. degree in electrical engineering from IIT Madras, and the master's degree in electrical engineering and the Ph.D. degree in computer science from Texas A&M University. After graduating from IIT Madras, he worked as an IC Design Engineer at Texas Instruments India, Bengaluru. He was a Post-Doctoral Fellow with the University of British Columbia and the Georgia Institute of Technology. He is currently an Associate Professor with the Department of Electrical Engineering, IIT Madras. His research interests include quantum and classical error correcting codes, quantum cryptography, quantum computation, and coding for distributed storage.

Abstract

Quantum computers promise to provide dramatic speedups over classical computers. However, noise poses an enormous hurdle to be crossed before they can be built and these speedups can be realized in practice. Fortunately, quantum codes offer a potential way out. In this talk we will give a brief introduction to the theory of quantum error correction with an emphasis on some of the salient developments in the last three decades. We will outline the challenges of quantum error correction and how the earliest quantum codes addressed these challenges and led to the general theory of quantum codes. Then, we will introduce stabilizer codes and their connections to classical codes. Within the framework of stabilizer codes we will present some important families of quantum codes with an emphasis on algebraic quantum codes. These families illustrate some of the primary methods of constructing stabilizer quantum codes.

We will then introduce the toric codes which are a class of topological codes. These codes are among the leading candidates for experimental quantum error correction. They also exploit the phenomenon of degeneracy which has no classical analogue. To build a scalable quantum computer quantum codes should also support fault tolerant quantum computation. We will discuss the need for fault tolerance and how quantum codes can support it. We will then introduce quantum low density parity check codes and report some of the recent advances in this area. We will conclude with a brief discussion on directions for further research including alternate models of quantum error correction.

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Code of Conduct for ICTS 2024

A code of conduct for a virtual conference ICTS 2024 has been established as guidelines for behaviour and interactions among attendees, speakers, and organizers.

1. **Respect:** Treat all participants with respect and consideration, valuing a diversity of views and opinions.

2. **Inclusivity:** Create an inclusive environment where everyone feels welcome, regardless of race, ethnicity, gender, sexual orientation, disability, age, religion, or other factors.

3. **Harassment-Free Zone:** Harassment and discriminatory behaviour will not be tolerated. This includes but is not limited to: offensive verbal comments related to race, gender, sexual orientation, disability, or religion; deliberate intimidation, stalking, following, or harassing photography or recording; sustained disruption of talks or other events; inappropriate physical contact; and unwelcome sexual attention.

4. **Professionalism:** Maintain professionalism in all interactions. Do not engage in disruptive behaviour that interferes with the conference proceedings.

5. **Privacy:** Respect the privacy of others. Do not share personal information about attendees without their consent.

6. **Appropriate Content:** Refrain from using language or sharing content that is offensive, abusive, or inappropriate for a professional setting.

7. **Intellectual Property:** Respect intellectual property rights. Do not share copyrighted material without permission.

8. **Reporting:** If you experience or witness any violations of the code of conduct, report it to the conference organizers immediately. They will investigate and take appropriate action.

9. **Q&A:** If you have any question for the speaker, please type it in chat window. We can take up those questions with the speaker if time permits. Please type questions for the speaker only in the chat window.

10. **Consequences:** Violation of the code of conduct may result in expulsion from the conference, and further action may be taken as necessary.

11. **Acknowledgment:** By participating in the conference, you acknowledge that you have read and agreed to abide by this code of conduct.