Narayanan Rengaswamy

Nov. 17, 2019

Ph.D. Candidate, Information Initiative at Duke (iiD)
Department of Electrical and Computer Engineering
Duke University, Durham, NC, USA

narayanan.rengaswamy@duke.edu
https://nrenga.github.io
https://www.linkedin.com/in/narayananrengaswamy/

EDUCATION

Ph.D. in Electrical Engineering, Jan. 2016 – Present *Cumulative GPA: 3.912 out of 4*
Duke University, Durham, NC, USA

Research: Quantum Information and Computation, Information and Coding Theory, Statistical Inference Problems
Advisors: Prof. Henry D. Pfister and Prof. Robert Calderbank
Coursework: Quantum Information Science I & II, Quantum Error Correction and Architectures, Compressed Sensing, Information Theory and Statistical Mechanics, Convex Optimization, Machine Learning, Basic Analysis I, Detection and Estimation Theory

M.S. in Electrical Engineering, Dec. 2015 *Cumulative GPA: 3.875 out of 4*
Texas A&M University, College Station, TX, USA

Thesis: On Cyclic Polar Codes and the Burst Erasure Performance of Spatially-Coupled LDPC Codes
Advisors: Prof. Henry D. Pfister and Prof. Krishna R. Narayanan
Coursework: Channel Coding, Statistical Communication Theory, Information Theory, Advanced Channel Coding, Computer Communication and Networking, Wireless Communications

B.Tech. in Electronics and Communication Engineering, May 2013 *Cumulative GPA: 9.70 out of 10 (3.88/4)*
Amrita University, Coimbatore, Tamilnadu, India

Project: Wireless Electrocardiogram Monitoring for Cardiac Patients on Android Platform
Advisor: Prof. E. P. Sumesh
Advanced Coursework: Wireless Communications, OFDM for Broadband Wireless Communications, Agent Based Modeling, Pattern Recognition, Convex Optimization

HONORS

DAAD RISE Professional Scholarship, 2015 *German Academic Exchange Service (DAAD)*
– One of the 34 scholarship recipients selected by the committee, among all the 184 applicants
– Funded the 3-month summer research internship in Alcatel-Lucent Bell Labs, Stuttgart, Germany

Top Rank in Undergraduate Studies, May 2013 *Amrita University*
– Ranked first in the college, third in the university (among 3 engineering campuses)

Ericsson Excel Certification in Telecommunications, 2012 *Amrita University*
– Attended leading Ericsson researcher's lectures, passed exam and completed an internship

Central Board of Secondary Education (CBSE) Merit Scholarship 2010-11 & 2011-12 *Amrita University*

Amrita TIDE Best Innovation Award, 2011-12 *Amrita University*
– As a team, developed an Integrated Village Development System; created a web portal for a job classifieds system
– Used Software Defined Radio (SDR) to demonstrate connectivity between places, with only partial internet dependence

RESEARCH

Research Assistant, Prof. Henry Pfister's Group, Jan. 2016 – Present *Duke University*
– Currently working on problems in quantum computation and quantum information
– Developed a systematic framework for synthesizing logical Clifford operators for arbitrary stabilizer codes
– Constructed an almost optimal size unitary 2-design using the symmetries of classical Kerdock codes
– Software implementations of all algorithms available at https://github.com/nrenga/symplectic-arxiv18a
– Developed a simple characterization of certain diagonal unitaries in the Clifford hierarchy

– Used this to characterize all stabilizer codes that support a given pattern of T and $T^\dagger$ gates on the physical qubits; proved a corollary that among all non-degenerate codes that have this property, CSS codes are optimal
– Carefully analyzed a recently proposed belief propagation algorithm for pure-state channels that passes quantum messages; using a 5-bit code as an example, performed calculations on the involved density matrices to show that this algorithm appears to be quantum optimal, i.e., reaches the joint Helstrom limit, even while making only single-qubit measurements
– Studied and prepared notes for understanding duality of channels and codes, based on a recent paper by Renes
– Conducted research on construction of deterministic compressed sensing matrices and recovery of large supports of unknown sparse vectors; demonstrated strong empirical evidence that Kerdock matrices outperform other constructions

Research Assistant, Prof. Henry Pfister's Group, Aug. 2014 – Dec. 2015 *Texas A&M University*
– Modified polar codes to produce cyclic polar codes of arbitrary blocklength, over appropriate Galois fields
– Achieved higher rates on the erasure channel than binary polar codes for a target block erasure rate

Research Assistant, Prof. Gregory Huff's Group, Jan. 2014 – Aug. 2014 *Texas A&M University*
– Worked on the MUSIC algorithm to triangulate and localize the origin of an ocean wave through its interaction with a network of buoy sensors; developed a C++ utility with Qt Creator IDE for field sensing and analysis

SKILLS

Core: Information and Coding Theory, Signal Processing, Quantum Information and Computation, Graphical Models and Inference, Linear and Abstract Algebra, Combinatorics, Probability, Wireless Communication
General: Theoretical Research, Teaching, Programming, Technical and Formal Writing
Languages: MATLAB, C, C++, Python, Arduino, Mathematica

TEACHING

Teaching Assistant, Error Correcting Codes, Fall 2017 *Duke University*

Teaching Assistant, Digital Audio Processing, Spring 2017 *Duke University*

Teaching Assistant, Capstone (Senior) Design, Spring and Fall 2015 *Texas A&M University*

Student Lectures, Channel Coding, Fall 2015 *Texas A&M University*

INDUSTRY EXPERIENCE

Graduate Research Intern, June – Aug. 2015 *Alcatel-Lucent Bell Labs, Stuttgart, Germany*
– Analyzed Spatially-Coupled Regular LDPC codes on burst erasure channels
– Proved that removal of 4-cycles and increasing left-degree can guarantee block erasure rates of $O(10^{-15})$ for some codes

Undergraduate Summer Intern, June – July 2012 *Ericsson India Global Services Private Limited, Chennai, India*
– Developed, with 5 fellow interns, a web portal (using Drupal and PHP) to facilitate the internal processing system of Ericsson's Revenue Management Division; prepared extensive documentation for the developed system

SELECTED PROJECTS

Quantum Belief Propagation and CQ Polar Codes, Course Project, Spring 2019 *Duke University*
– Understood the recently introduced belief propagation algorithm that decodes classical binary linear codes on a pure-state channel by passing qubits as messages
– Constructed a 5-bit code example, performed full performance analysis for QBP on each bit, and compared to the optimal Helstrom strategy for each bit
– Summarized the connection to pure-loss optical channel and the capacity-achieving classical-quantum (CQ) polar codes

Decoding the Surface Code, Course Project, Fall 2018 *Duke University*
– Built the minimum-weight perfect matching (MWPM) decoder from scratch using MATLAB's optimization routines
– Verified the well-known surface code thresholds via extensive simulations
– Partially built the recently introduced "Blossom-Belief Propagation" algorithm for MWPM
– Report online: `https://dx.doi.org/10.13140/RG.2.2.27511.47522`

Efficient Classical Simulation of Quantum Circuits, Course Project, Fall 2018 *Duke University*
– Read and summarized the `CHP` simulator and the more recent stabilizer rank-based simulator
– Reviewed the symplectic representation of Clifford group and used it to succinctly describe the `CHP` simulator
– Report online: `https://dx.doi.org/10.13140/RG.2.2.20800.58887`

Hands On, Course Project, Fall 2013 *Texas A&M University*
– As a team, developed a device for testing coordination of both hands simultaneously
– Developed a GUI using Qt Creator IDE to receive and visualize Inertial Measurement Unit (IMU) data real-time
– Performed real-time testing with voluntary participants on Demo Day

Wireless Electrocardiogram (ECG) Monitoring, B.Tech. Project, Jul. 2012 – May 2013 *Amrita University*
– As a team, built hardware to transmit ECG (input from a reliable, mobile ECG extractor) to phone over Bluetooth
– Developed an Android application to receive signals from hardware in real-time and display it along with key parameters
– Processed the signals using the Pan-Tompkins algorithm to detect key parameters, and raised alerts when necessary via the Short Message Service (SMS)

PROFESSIONAL ACTIVITIES

Project Manager for Duke Opportunities in Math (DOmath), June - July 2018 *Duke University*
– Mentored 3 students in a two-month project performing randomized benchmarking on IBM's *ibmqx4* device. Project lead by Prof. Robert Calderbank and Prof. Henry Pfister. Report: `https://math.duke.edu/domath2018`

Quantum Group Meetings, Mar. 2017 – Present *Duke University*
– Organizing weekly meetings on topics related to quantum information, computation, communications, algorithms
– Presented papers and my notes on several topics of interest, most recently on our work on codes that support T gates

North American School of Information Theory, June 2016 *Duke University*
– Assisted in organizing the summer school, handled monetary responsibilities
– Developed an information-theory crossword puzzle (with a colleague) to illustrate iterative decoding

Workshop on Software Defined Radio, Aug. 2012 *Amrita University*
– Learned to work with the Universal Software Radio Peripheral (USRP) Kit
– Developed simple communications system modules in GNU Radio Companion software

Graduate Student Member of IEEE, since Nov. 2015

Reviewer for IEEE Transactions on Information Theory, since 2016

Reviewer for IEEE International Symposium on Information Theory, 2018

Reviewer for IEEE Information Theory Workshop, 2018

Reviewer for IEEE Transactions on Vehicular Technology, since 2019

THESES

1. N. Rengaswamy, "On Cyclic Polar Codes and the Burst Erasure Performance of Spatially-Coupled LDPC Codes," Master's thesis, Texas A&M University, 2015. [Online]. Available: `http://hdl.handle.net/1969.1/156244`.

PEER-REVIEWED JOURNAL PAPERS

2. **N. R.**, R. Calderbank, and H. D. Pfister, "Unifying the Clifford hierarchy via symmetric matrices over rings," *Phys. Rev. A*, vol. 100, no. 2, p. 022304, 2019. [Online]. Available: `http://arxiv.org/abs/1902.04022`

1. V. Aref, **N. R.**, and L. Schmalen, "Finite-Length Analysis of Spatially-Coupled Regular LDPC Ensembles on Burst-Erasure Channels," *IEEE Trans. Inform. Theory*, vol. 64, no. 5, pp. 3431 – 3449, 2018. [Online]. Available: `https://arxiv.org/abs/1611.08267`.

PREPRINTS

5. **N. R.**, K. Seshadreesan, S. Guha, and H. D. Pfister, "Belief-Propagation with Quantum Messages on Pure-State Channels," *In preparation, to be posted on arXiv*, 2019.

4. **N. R.**, R. Calderbank, M. Newman, and H. D. Pfister, "On Optimality of CSS Codes for Transversal T," *arXiv preprint arXiv:1910.09333*, 2019. [Online]. Available: `http://arxiv.org/abs/1910.09333`

3. **N. R.**, R. Calderbank, S. Kadhe, and H. D. Pfister, "Logical Clifford Synthesis for Stabilizer Codes," *Submitted to Quantum, arXiv preprint arXiv:1907.00310*, 2019. [Online]. Available: `http://arxiv.org/abs/1907.00310`

2. T. Can, **N. R.**, R. Calderbank, and H. D. Pfister, "Kerdock Codes Determine Unitary 2-Designs," *Submitted to IEEE Trans. Inf. Theory, arXiv preprint arXiv:1904.07842*, 2019. [Online]. Available: `http://arxiv.org/abs/1904.07842`.

1. **N. R.**, R. Calderbank, S. Kadhe, and H. D. Pfister, "Synthesis of Logical Clifford Operators via Symplectic Geometry," *arXiv preprint arXiv:1803.06987*, 2018. [Online]. Available: `http://arxiv.org/abs/1803.06987`.

PEER-REVIEWED CONFERENCE PAPERS

5. T. Can, **N. R.**, R. Calderbank, and H. D. Pfister, "Kerdock Codes Determine Unitary 2-Designs," in *Proc. IEEE Int. Symp. Inform. Theory*, pp. 2908–2912, July 2019.

4. **N. R.**, R. Calderbank, S. Kadhe, and H. D. Pfister, "Synthesis of Logical Clifford Operators via Symplectic Geometry," in *Proc. IEEE Int. Symp. Inform. Theory*, pp. 791–795, June 2018.

3. V. Aref, **N. R.**, and L. Schmalen, "Spatially Coupled LDPC Codes Affected by a Single Random Burst of Erasures," in *Proc. Int. Symp. on Turbo Codes & Iterative Inform. Process.*, pp. 166–170, Sep. 2016. [Online]. Available: `https://arxiv.org/abs/1607.00918`.

2. **N. R.**, L. Schmalen, and V. Aref, "On the Burst Erasure Correctability of Spatially Coupled LDPC Ensembles," in *Proc. IEEE Intl. Zurich Seminar on Commun.*, pp. 155–159, March 2016.

1. **N. R.** and H. D. Pfister, "Cyclic Polar Codes," in *Proc. IEEE Int. Symp. Inform. Theory*, pp. 1287–1291, June 2015.

VISITS, TALKS, POSTERS AND WORKSHOPS

16. Talk – "On Optimality of CSS Codes for Transversal T", *Institut Quantique Seminar*, Université de Sherbrooke (Host: Prof. David Poulin), Oct. 28, 2019, and *Institute for Quantum Computing (IQC) Seminar*, University of Waterloo (Host: Prof. David Gosset), Nov. 5, 2019. Accepted to QIP 2020 for a talk.

15. Visit – Prof. Jean-Pierre Tillich, *INRIA Research Center*, Paris, July 22-25, 2019.

14. Talk – "Integer Symmetric Diagonal (ISD) Gates and Codes that Support Physical T Gates", *Quantum Information Seminar*, Technical University of Delft (Host: Prof. Barbara Terhal), July 16, 2019, and University of Sheffield (Host: Prof. Earl Campbell), Aug. 5, 2019.

13. Poster – "Unifying the Clifford Hierarchy via Symmetric Matrices over Rings", *14th Conference on the Theory of Quantum Computation, Communication and Cryptography*, University of Maryland, Jun. 3-7, 2019, and *5th International Conference on Quantum Error Correction*, Senate House, London, July 29 – Aug. 2, 2019.

12. Poster – "Kerdock Codes Determine Unitary 2-Designs", *22nd Annual Conference on Quantum Information Processing*, University of Colorado Boulder, Jan. 14-18, 2019, and *14th Conference on the Theory of Quantum Computation, Communication and Cryptography*, University of Maryland, Jun. 3-7, 2019.

11. Poster – "Symplectic Matrices for Logical Clifford Synthesis and Diagonal Unitaries in the Clifford Hierarchy", *22nd Annual Conference on Quantum Information Processing*, University of Colorado Boulder, Jan. 14-18, 2019.

10. Poster – "Synthesis of Logical Clifford Operators via Symplectic Geometry", *13th Conference on the Theory of Quantum Computation, Communication and Cryptography*, University of Technology Sydney, Jul. 14-20, 2018.

9. Poster – "Synthesis of Logical Operators for Quantum Computers using Stabilizer Codes", *North American School of Information Theory*, Texas A&M University, May 20-23, 2018.

8. Talk – "Synthesis of Logical Operators for Quantum Computers using Stabilizer Codes", *Seminar, Department of Electrical Engineering*, Indian Institute of Technology Madras (Host: Prof. Pradeep Sarvepalli), Apr. 26, 2018.

7. Poster – "Logical Operators for CSS Codes: A Binary Perspective", *Duke IBM Day*, Duke University, Oct. 31, 2017.

6. Workshop – *Beyond I.I.D. in Information Theory*, National University of Singapore, Jul. 24-28, 2017.

5. Poster – "Deterministic Compressed Sensing and Recovery of Large Supports", *North American School of Information Theory*, Georgia Institute of Technology, Jun. 6-9, 2017.

4. Workshop – *Communications, Inference, and Computing in Molecular and Biological Systems*, University of Southern California, Dec. 3-4, 2015.

3. Talk – "The Burst Erasure Correctability of Spatially Coupled LDPC Ensembles", *Information Sciences and Systems Seminar*, Texas A&M University, Nov. 4, 2015.

2. Talk – "Cyclic Polar Codes", *Information Sciences and Systems Symposium*, Texas A&M University, Oct. 19, 2015.

1. Poster – "Cyclic Polar Codes: How to Achieve Higher Rates than Binary Polar Codes at Finite Blocklengths?", *Eighth Annual Winedale Workshop*, Round Top, Texas, Oct. 9, 2015.

REFERENCES

1. **Prof. Henry D. Pfister**, Department of ECE, Duke University, `pfister.ee.duke.edu`
2. **Prof. Robert Calderbank**, Department of ECE, Duke University, `ece.duke.edu/faculty/robert-calderbank`
3. **Prof. Kenneth R. Brown**, Department of ECE, Duke University, `ece.duke.edu/faculty/kenneth-brown`
4. **Prof. Saikat Guha**, College of Optical Sciences, University of Arizona, `sites.google.com/site/saikatguha/`
5. **Prof. Iman Marvian**, Department of ECE, Duke University, `ece.duke.edu/faculty/iman-marvian`