DIMACS Center
Rutgers University

DIMACS Research Experiences for Undergraduates (REU) Program

Annual Report

January 2006

Ia. Participants from the program

Participants:

Organizers:

Fred Roberts, Director, DIMACS, Rutgers University
Designed and managed the program. Coordinated with DIMATIA. Recruited mentors and applicants. Managed graduate student coordinators. Assessed program and met reporting requirements.

Martin Balek, REU Graduate Coordinator, Charles University
Developed and managed social activities, seminars, and field trips. Mentored participants. Guided participants in preparing presentations. Managed trip to Czech Republic.

Mel Janowitz, Associate Director, DIMACS, Rutgers University
Evaluated applicants.

Janos Komlos, Dept. of Mathematics, Rutgers University
Recruited mentors and applicants. Managed graduate student coordinators. Met with participants weekly at Rutgers University.

Brenda Latka, Associate Director, DIMACS, Rutgers University
Recruited mentors and applicants. Evaluated applicants and managed applicant selection. Publicized program outcomes. Assessed program and met reporting requirements. Interfaced with REU organizers at other sites.

Jaroslav Nesetril, Director, DIMATIA, Charles University, Prague, Czech Republic
Designed and managed program. Coordinated with DIMACS. Recruited Czech mentors and applicants. Publicized program. Evaluated applicants and managed Czech applicant selection. Managed graduate student coordinators. Met with participants at Charles University.

Lara Pudwell, REU Graduate Coordinator, Rutgers University
Evaluated applicants. Developed and managed website, social activities, seminars, and field trips. Mentored participants. Guided participants in preparing presentations. Managed trip to Czech Republic. Assessed program and met reporting requirements.

US Faculty Mentors:

Eric Allender, Department of Computer Science, Rutgers University
Served as co-mentor to the students from Charles University. Provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Endre Boros, RUTCOR, Rutgers University
Served as co-mentor to Kathryn Davidson, Elizabeth Hayden, and Daniel MacDonald. Helped with selection of participants, provided research topics, met with students weekly or as needed,

critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Ovidiu Costin, Department of Mathematics, Rutgers University
Served as co-mentor to Shana Lieberman. Provided a research topic, met with student weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Rodica Costin, Department of Mathematics, Rutgers University
Served as co-mentor to Shana Lieberman. Provided a research topic, met with student weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Wanpracha (Art) Chaovalitwongse, Department of Industrial Engineering, Rutgers University
Served as mentor to Abhinav Jha and Jessica McCoy. Helped with selection of participants, provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Stanley Dunn, Biomedical Engineering, Rutgers University
Served as mentor to Aziza Jefferson, Karen Lostritto, and Jennifer Staigar. Helped with selection of participants, provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Martin Farach-Colton, Department of Computer Science, Rutgers University
Served as mentor to Andrew Rodriguez. Helped with selection of participants, provided a research topic, met with student weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Vladimir Gurvich, RUTCOR, Rutgers University
Served as co-mentor to Kathryn Davidson, Elizabeth Hayden, and Daniel MacDonald. Helped with selection of participants, provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Paul Kantor, SCILS, Rutgers University
Served as mentor to Jordanna Chord and Melissa Mitchell. Helped with selection of participants, provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers

Jeff Kahn, Department of Mathematics, Rutgers University
Served as co-mentor to the students from Charles University. Provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Joel Lebowitz, Department of Mathematics, Rutgers University
Served as mentor to Jonathan Bergknoff. Provided a research topic, met with student weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Michael Littman, Department of Computer Science, Rutgers University

Served as mentor to Arjun Talwar. Helped with selection of participants, provided a research topic, met with student weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Vadim Lozin, RUTCOR, Rutgers University
Served as mentor to Sarah Bleiler and Samuel Nelson. Helped with selection of participants, provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

S. Muthu Muthukrishnan, Department of Computer Science, Rutgers University
Served as mentor to Craig Bowles and Khanh Do Ba. Helped with selection of participants, provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Wilma Olson, Department of Chemistry, Rutgers University
Served as mentor to Yi Lin. Helped with selection of participants, provided a research topic, met with student weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Avy Soffer, Department of Mathematics, Rutgers University
Served as mentor to Alekzander Malcom and Charles Siegel. Provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Christopher Woodward, Department of Mathematics, Rutgers University
Served as mentor to Matthew Meola and Joseph Walsh. Provided research topics, met with students weekly or as needed, critiqued oral presentations, helped with writing papers, and attended presentations given at Rutgers.

Faculty Mentors in Prague:

Martin Klazar, Charles University
Jan Kratochvil, Charles University
Martin Loebl, Charles University
Jiri Matousek, Charles University
Jaroslav Nesetril, Charles University and Director of DIMATIA
Pavel Valtr, Deputy Head, Charles University

DIMACS REU Domestic Program Students:

Jordanna Chord, Gonzaga University
Josef Cibulka, Charles University
Kathryn Davidson, University of Pennsylvania
Khanh Do Ba, Dartmouth College
Elizabeth Hayden, Coe College
Jan Hladky, Charles University
Abhinav Jha, Rutgers University
Marek Krcal, Charles University
Yi Lin, Emory University

Karen Lostritto, Brown University
Daniel MacDonald, Seton Hall University
Jessica McCoy, North Carolina State University

DIMACS REU/RISE Program Students:

Andrew Rodriguez, University of Texas at San Antonio
Alisa Stephens, University of Maryland

DIMACS REU Prague Program Students:

Sarah Bleiler, Seton Hall University
Craig Bowles, Cornell University
Melissa Mitchell, University of Detroit – Mercy
Samuel Nelson, Bucknell University
Arjun Talwar, Stanford University

Department of Mathematics REU Program Students:

Jonathan Bergknoff, Cornell University
Aziza Jefferson, Rutgers University
Shana Lieberman, Goucher College
Alekzander Malcom, University of Texas at Arlington
Matthew Meola, Rutgers University
Jennifer Staigar, Rutgers University
Charles Siegel, Rutgers University
Joseph Walsh, Rutgers University

Seminar Speakers:

Tanya Berger-Wolf, DIMACS Postdoctoral Associate, Rutgers University
Endre Boros, Professor of Operations Research, RUTCOR, Rutgers University
Dominique Foata, Institut Lothaire - Strasbourg, France
Ian Levitt, Graduate Student, Department of Mathematics, Rutgers University
Diane Maclagan, Professor of Mathematics, Rutgers University
Lara Pudwell, Graduate Student, Department of Mathematics, Rutgers University
Bruce Sagan, DIMACS visitor, Michigan State University
Scott Schneider, Graduate Student, Department of Mathematics, Rutgers University
Vince Vatter, Graduate Student, Department of Mathematics, Rutgers University
Elaine Weyuker, AT&T Labs

Visiting Lafayette REU Program Speakers:

Jenna Bratz, Lafayette College
Patricia Cahn, Smith College
Ayden Gerek, Lafayette College
Michael Greenberg, NYU
Nick Haber, Brown University
Brian Krummel, UMBC
Karen McCready, The College of New Jersey
Kenneth P. Ober, Bard College

Sarah M. Tekansik, Mesa State
Matthias Youngs, SUNY Geneseo

Ib. Participating Organizations

Telcordia Technologies: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series. Telcordia hosted a field trip.

AT&T Labs - Research: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

NEC Research Institute Inc: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Lucent Technologies, Bell Labs: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

IBM Research: Facilities; Personnel Exchanges
Affiliated organization of DIMACS. Individuals from the organization participated in the program planning and seminar series. IBM Research hosted a field trip.

Princeton University: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Avaya Labs: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Georgia Institute of Technology: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

HP Labs: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Microsoft Research: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Rensselaer Polytechnic Institute: Facilities; Personnel Exchanges
Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Stevens Institute of Technology: Facilities; Personnel Exchanges

Partner organization of DIMACS. Individuals from the organization participated in the program planning and seminar series.

Charles University: Financial Support; Facilities; Collaborative Research; Personnel Exchanges
DIMATIA is a major research center at Charles University in Prague, Czech Republic, and our partner in the program.

Lafayette College; Personnel Exchanges
Mentors and students from the Lafayette College REU program visited DIMACS.

II. Project Activities

The DIMACS/DIMATIA REU program had the following three parts: (i) A group of students from all across the U.S. participated in an 8-week REU program headquartered at DIMACS; (ii) A second group of five students from all across the U.S. participated in the 8-week domestic REU program and then spent 3 additional weeks at DIMATIA; (iii) a group of students from the Czech Republic participated in the 8-week domestic REU program and then acted as hosts at DIMATIA when the U.S. students went to Prague. We collaborated with the Rutgers Department of Mathematics REU program, with participants from the two programs sharing office and living space, attending the same seminars, and participating in shared mentoring activities. We were also affiliated with the Research in Science and Engineering (RISE) program at Rutgers/UMDNJ, sharing two students with that program, which emphasizes research opportunities for under-represented groups.

IIA. Research and Education Activities

1. Recruitment Activities

The program website served as a source of information about the program and application process. In addition, 700 flyers were mailed to mathematics, statistics, and computer science departments. The mailing list targeted both some of the more “elite” math programs such as Harvard, Harvey Mudd, Brown, CMU, etc. as well as minority institutions. In addition, the Director made personal contacts with faculty in minority institutions to identify potential applications and offer encouragement. The DIMACS REU has also been associated with other summer programs at Rutgers specifically targeted at minority students. In 2005 two students were “shared” between our program and the Research in Science and Engineering (RISE) program at Rutgers/UMDNJ, with a custom tailored program to fit the interests of each individual student.

2. Applicant Pool and Selection

The two DIMACS Associate Directors and the Rutgers Graduate Student Coordinator initially evaluated applicants for their appropriateness for the projects in which they were interested. The mentors made the final choices of applicants. They considered those applicants who had the appropriate background for the project and expressed the most interest. The DIMACS Director approved the selections and assisted with decisions as to optimal placement for students. One of the Associate Directors, in consultation with the Director, chose which 5 of the participants would also travel to Prague based on their background in combinatorics.

The DIMACS program has been especially successful in attracting strong women candidates.

Our projects place an emphasis on the applications of mathematics and computer science in areas traditionally of interest to women. The following tables aggregate data for all our joint programs.

	Applicants	%	Participants	%
Women	39	34%	12	48%
Men	77	66%	13	52%
Total	116		25	

	Applicants	%	Participants	%
African Amer/Hispanic	10	9%	3	12%
Asian	20	17%	3	12%
Caucasian	55	47%	12	48%
Info Not Provided	31	27%	7	28%
Total	116		25	

	Applicants	%	Participants	%
NY/NJ/PA	42	36%	13	52%
Northeast	10	9%	2	8%
Southeast	20	17%	5	20%
Midwest	23	20%	3	12%
West	16	14%	1	4%
Other	5	4%	1	4%
Total	116		25	

3. Project Descriptions

Eric Allender, Computer Science Department, Rutgers University

Project Title: Planarity Testing
The testing of planarity of a graph is in a complexity class that can be solved using a Turing machine with logarithmic space. The classification of planarity testing was proved by applying a very complicated algorithm. The goal of this project is to use older planarity testing methods and a reduction technique to simplify the proof.

Endre Boros, RUTCOR, Rutgers University
Vladimir Gurvich, RUTCOR, Rutgers University

Project Title: Machine Learning
A simple generalization of decision tree based learning methods is applied to medical test results. The project involves finding methods that allow the most error tolerance but create the simplest and most useful formulas for making diagnoses.

Project Title: Generation of Shortest Paths and Minimal Cutsets

The project explores how to generate short paths from initial vertex s to terminal vertex t with acceptable computational complexity. Minimal ways to cut those short paths are also considered.

Ovidiu Costin, Department of Mathematics, Rutgers University
Rodica Costin, Department of Mathematics, Rutgers University

Project Title: Connections Constants in Differential Systems
This problem has a long history, and is illustrated by the question of determining the behavior of a system as t approaches infinity when data is given as t goes to negative infinity. The project aims at developing a new methodology to attack this issue in settings when solutions cannot be expressed in any usable closed form.

Wanpracha (Art) Chaovalitwongse, Department of Industrial Engineering, Rutgers University

Project Title: Marine Logistics: Crude Oil Transportation
Marine logistics has a near monopoly on transportation of large volumes of goods between continents. Although routing problems have been extensively studied, very little of that research is devoted to marine transportation problems. This project involves developing a complete mathematical programming formulation for the routing, transportation, scheduling, and inventory management of a single bulk product (in this case, crude oil) with a production and demand profile that changes daily.

Project Title: Flight Scheduling
The Pacific oceanic airspace includes flights connecting Australia/New Zealand, Asia, and North America/Hawaii. This airspace alone experiences an average of 700 flights every single day, with little variation throughout the year. Five sets of fixed track systems comprise the airspace, and this project focused on the Pacific Organized Track System (PACOTS). This project involves making enhancements to current scheduling systems, so that flight requests are accommodated with minimal adjustment while maintaining separation regulations of both level and time.

Stanley Dunn, Biomedical Engineering, Rutgers University

Project Title: Virology Tiling Theory
The purpose of this project is to examine the capsid structure of viruses and determine if all combinations of the proteins in the capsid can be determined mathematically.

Project Title: Eulerian Graph Representation for siRNA Sequence Structure
This project involves exploring weighted graph models of siRNA sequences to determine which graph properties distinguish between functional and nonfunctional siRNA.

Project Title: Tensor Decomposition of Microarray Data
The goal of this project is to investigate empirical, or data-driven methods for analyzing DNA microarrays. Boosting, bootstrapping and factor space methods will be considered as techniques to develop algorithms for identifying genes clustered by expression as well as identifying regulatory relationships.

Martin Farach-Colton, Department of Computer Science, Rutgers University

Project Title: Experimental Evaluation of Hop-optimal Networks in the Weak Sensor Model
This project involves experimentally evaluating an optimal distributed algorithm for a sensor network formation. The model that describes the topology of such a resulting network is a

Constant-degree Hop-optimal Spanning Subgraph (CHSG). In this work, properties of the network obtained by the algorithm, such as connectivity and hop-stretch, are evaluated through simulation.

Paul Kantor, SCILS, Rutgers University

Project Title: Author Identification Challenge
We would like to be able to distinguish authors by their choice of words when writing. Which words matter? How do we know? These are classic questions posed in discussing the Federalist Papers, but now we are trying to apply the concept to identify authors in millions of email messages. What are the right features? What kind of machine learning is required? What statistical theories may govern the process?

Jeff Kahn, Department of Mathematics, Rutgers University

Project Title: Graph Theory Conjectures
Problem 1: Let G be an undirected graph. We call its subgraph a forest, if it doesn't contain any cycle. Denote by n, n(e), n(ef) the number of all forests contained in G, those containing edge e and those containing both e and f, respectively. The conjecture which we are trying to prove or disprove says that $n * n(ef) \leq n(e) * n(f)$.
Problem 2: We denote by A,B a path between vertices s and t, respectively between u and v. In this case it seems that $n(AB) * n \geq n(A) * n(B)$. It was proved that if the first conjecture is true, then this one is true, as well.
Problem 2': Let X be a subset of vector space V. Let x,y be from V. If x can be written as a linear combination of vectors from X, we say that x lies in the span of X. Let n, n(x), n(xy) denote the number of all independent subsets of X, those containing x in their span and those containing both x and y in their span, respectively. The conjecture is that $n) * n(xy) \geq n(e)) * n(f)$. This conjecture is believed not to be true, but no one has found a counterexample yet.
Problem 3: Let T be a binary tree with some of its vertices colored with 4 colors. We are also given the colors of its leaves. Now we randomly properly color (i.e.vertices sharing an edge must have different colors) all the remaining vertices. For each color i, we have probability p(i), that the root is colored by i. The question is whether those probabilities change if we change the colors of the leaves. This is obviously not true when the depth of the tree is small, but we want to show that the probabilities are becoming more and more similar when the depth grows to infinity.

Joel Lebowitz, Department of Mathematics, Rutgers University

Project Title: Ionization of a Two-Level System
We are interested in the probability of an atom ionizing in the presence of an electric field. The atom is to be modeled as having two bound states and a continuum of scattering states. In this model, ionization corresponds to an escape to the continuum.

Michael Littman, Department of Computer Science, Rutgers University

Project Title: Game Theory
Games come in many varieties. Some are represented by trees, some by directed graphs, with cycles or without. Rewards in these games are either accumulated after every move (edge rewards) or come in a big bang at the end (leaf rewards). Some games have randomness (stochastic), some don't (deterministic). We are interested in all such games of perfect information with two players. This project involves finding algorithms that find appropriate Nash equilibria, i.e. stable states of an arbitrary game, in polynomial time

Vadim Lozin, RUTCOR, Rutgers University

Project Title: Applications of the Maximum Independent Set Problem
The Maximum Independent Set (MIS) problem is a famous problem in graph theory. A set of vertices of a graph is an independent set if no two vertices in the set are connected by an edge. The MIS problem is essentially finding an independent set of a graph G that contains the most possible vertices. The number of vertices in this set is known as the independence number. In general, the MIS problem is NP-complete. However, there are specific classes of graphs for which the problem can be solved in polynomial time. For all others, it is important to find techniques and algorithms that can efficiently approximate the independence number.
The Maximum Independent Set problem has many uses in areas of computer vision, pattern recognition, and information/coding theory. This project involves researching its applications in these areas as well as trying to find and explore further practical applications.

Project Title: Graph Theory
This project involves the 3-colorability problem, that is, assigning each vertex in a graph one of 3 colors such that no two adjacent vertices receive the same color. We wish to identify classes of graphs for which the 3-colorability problem is solvable in polynomial time, and classes of graphs for which the 3-colorability problem is solvable in NP-complete time. Furthermore, we wish to give coloring algorithms for these graphs and prove their time complexity.

S. Muthu Muthukrishnan, Department of Computer Science, Rutgers University

Project Title: Non-Clairvoyant Job Scheduling
In a scheduling problem, one is given a set of jobs with various processing times with the goal of minimizing or maximizing some value given some constraints. This project involves the stretch, which is the ratio of a job's completion time to its processing time. This metric, which has only been looked at recently, seems useful because it measures a schedule's success with respect to the size of the job being requested.

Project Title: Estimating Entropy and Entropy Norm on Data Streams
Data stream mananagement systems (DSMSs) and some database management systems (DBMSs) often must deal with massive flows of data much too long to store locally yet need to be mined for useful information. In particular, most functions on the data are impossible to compute exactly, and must be approximated to some degree of accuracy using randomization. The first part of this project is designing an algorithm to approximate the quantity called the entropy norm. The second part of the project involved designing an algorithm to approximate the empirical entropy efficiently.

Wilma Olson, Department of Chemistry, Rutgers University

Project title: Protein-induced DNA Looping
Many genetic processes are mediated by proteins that bind at separate, often widely spaced, sites on the double helix, tethering the intervening DNA into a loop. As a first step in understanding the effects of specific proteins and drugs on DNA looping, we propose to study the imposed bending and twisting of neighboring base pairs in known complexes of proteins and drugs with double helical DNA stored in the Nucleic Acid Database. By subjecting a DNA segment of the same chain length as that found in a given complex to the observed orientation, displacement, and superhelical stress and setting the elastic moduli to sufficiently high values, we can use existing program to simulate the presence of a rigidly bound molecule at arbitrary positions on circular

DNA molecules or to model specific systems in which DNA looping plays an important role, e.g., the lac repressor-operator assembly in EscherichiaA0coli.

Avy Soffer, Department of Mathematics, Rutgers University

Project Title: Error Bounds for the Approximation to Solutions of the Schrodinger Equation
This project involves approximating the solution to the Schrodinger equation on some finite domain by the common practice of introducing an imaginary "potential" into the equation $i\frac{\partial u}{\partial t} = -\nabla^2 u$. More importantly, error bounds for the difference in the actual solution in the domain and this approximate solution will be found, thus evidencing some sort of validity to the method.

Project Title: Error Analysis in PDEs
This project involves finding numerical solutions to the wave equation, that is, $u_{tt}=\Delta u$, with a boundary condition on the surface of the object we're studying such that the wave will be reflected. The goal is to prove that the error is less than cε/tn and to find c and n.

Christopher Woodward, Department of Mathematics, Rutgers University

Project Title: A Study of Knot and Tangle Invariants
The project involves the study of knots and tangles, isotopy, and Reidemeister moves.

4. Other Academic Activities

A unique aspect of our REU program is its place within a vital and active research center with many other exciting programs, which are made available to our REU students. The richness of the intellectual community and the international flavor contributed by the many foreign scientists participating in DIMACS and DIMATIA activities at the same time as the REU students added to the overall atmosphere. The students in the REU made connections with a variety of other DIMACS programs, including tutorials, workshops, and seminars, and we encouraged them to get involved with our industrial partners to expose them to industrial research as well as with our other partners such as the Institute for Advanced Study. Many of the students attended talks in biology related DIMACS Workshops such as the ones on Information Processing by Protein Structures in Molecular Recognition, Detecting and Processing Regularities in High Throughput Biological Data, and Evolutionary Considerations in Vaccine Use or attended the DIMACS Computational and Mathematical Epidemiology Seminar. The 2005 REU program coincided with the DIMACS Bio-Math Connect Institute (BMCI), which provides research experiences for high school teachers and connects them with active researchers in bioinformatics and computational biology. The REU students interacted with both the high school teachers and researchers in BMCI.

There was a weekly DIMACS REU Seminar Series hosting both local speakers and renowned outside speakers. The seminars were preceded by lunch and followed by opportunities to interact with the speakers. One of these seminars was devoted to a presentation about graduate school. Another was a workshop on how to give a presentation. The effectiveness of this workshop was evident from the high quality of the presentations made by the students during the course of the program.

We introduced the students to industrial research by making trips to Telcordia Technologies and to IBM Research, where our students participated in tours and technical presentations. Just as we feel it is important for the students to be exposed to multiple (and international) academic environments, we also found that the students were served well by the opportunity to explore two different corporate environments.

Weekly seminars and workshops

Thursday, June 9, REU Workshop
Topic: Panel on Graduate School in Math/Computer Science

Tuesday, June 14, REU Seminar
Title: The card game Set
Speaker: Dr. Diane Maclagan, Professor of Mathematics, Rutgers University

Thursday, June 16, REU Seminar
Title: Combinatorics and Special Functions: the Hermite Polynomials
Speaker: Dr. Dominique Foata, Institut Lothaire - Strasbourg, France

Thursday, June 16, REU Workshop
Topic: How to Give a Presentation
Speakers: Scott Schneider and Lara Pudwell, Mathematics Graduate Students, Rutgers University

Monday, June 20, Telcordia Visit

Tuesday, June 21, REU Seminar
Title: How Good (or Bad) Can Stable Marriages Be?
Speaker: Dr. Endre Boros, Professor of Operations Research, RUTCOR, Rutgers University

Thursday, June 23, Project Presentations

Friday, June 24, Project Presentations

Tuesday, June 28, REU Seminar
Title: Maximal Independent Sets in Graphs
Speaker: Dr. Bruce Sagan, DIMACS visitor, Michigan State University

Wednesday, June 29 REU/RISE Workshop
Topic: Panel on Navigating Graduate School

Tuesday, July 5, REU Seminar
Title: Persistent Social Structures
Speaker: Dr. Tanya Berger-Wolf, DIMACS Postdoctoral Associate

Wednesday, July 6, REU/RISE Seminar
Speaker: Dr. Elaine Weyuker, AT&T Labs

Monday, July 11, IBM Visit

Tuesday, July 12, REU Seminar
Title: Packing Densities of Permutations
Speaker: Vince Vatter, Mathematics Graduate Student, Rutgers University

Thursday, July 14, REU Workshop
Topic: What to Expect in Prague
Speakers: DIMATIA REU students

Wednesday, July 20, Lafayette REU Presentations
Final Project Presentations

Thursday, July 21, Final Project Presentations

Tuesday, July 26, REU Seminar
Title: Linear Programming Duality
Speaker: Ian Levitt, Mathematics Graduate Student, Rutgers University

5. Social and Community Building Activities

Throughout the summer the students were invited to planned group social activities. There was an orientation dinner, as well as an outdoor barbeque during the first week of the program to encourage students to mingle and meet one another. Both of these events had nearly 100% participation and received positive reviews from the students. Every few weeks during the program, another group activity such as movie night, game night, etc., was held. We encouraged students to plan their own activities and they did so, including volleyball games and chess tournaments. But it was also important to have formally planned activities for all the students to facilitate interaction beyond the smaller groups that formed from research teams and housing arrangements. These activities continued to be well attended throughout the program.

Tuesday, June 7	Orientation Dinner
Tuesday, June 7	Housing Orientation
Saturday, June 11	Barbeque/Cookout
Friday, June 24	Movie Night
Thursday, June 30	Volleyball (organized by REU student)
Monday, July 4	Chess Tournament (organized by REU student)
Friday, July 15	Pizza/Games Night
Thursday, July 21	Farewell Dinner
Friday, July 22	Volleyball (organized by REU student)

In addition, there were lunches and dinners involved with all of the seminars, workshops, and field trips, giving the students additional opportunities to interact and serving as an interface between the social and research activities.

In Prague, the students joined faculty at lunches during the DIMACS/DIMATIA/Renyi working group meeting on Extremal Combinatorics and went on several cultural excursions organized by the Czech students.

IIB. Findings

Meeting a Challenge of the Intelligence Community: Using Writing Characteristics to Identify Authors

Jordanna Chord, Gonzaga University, and Melissa Mitchell, University of Detroit – Mercy, worked with Paul Kantor, SCILS, Rutgers University, exploring the following question: Given several authors, can you tell them apart by the characteristics of their writings?

The intelligence community, which supports Paul Kantor's work, defined a "challenge problem" which approximates the real problem that they face. They provided a set of items to be separated by "author." To prepare for this challenge problem, Chord, Mitchell, and Kantor selected ten "author names" for which there is one prolific contributor, and approximately an equal number of papers by others. They drew associated abstracts, address information, and keywords from the online database Pubmed and applied Bayesian Binary Regression to identify authors using a combination of seven document attributes. They achieved strong performance (defined as a Receiver Operating Characteristic with an area under the curve of 80% or better), in several ways. They used only keywords, only addresses, or a representation that included all attributes: abstract words, address words, address fields, co-authors, keywords, and title.

One expects the use of all variables to give the best performance. Chord, Mitchell, and Kantor's results surprisingly identified keywords and addresses as working well alone in identifying documents. Future research includes the tests of a new feature: a "network" of authors to test whether author connections is a strong identifying feature.

Jordanna Chord was invited to present her summer research results at the Seventh Annual Northwestern Regional Conference of the Consortium for Computing Sciences in Colleges, October 14 & 15, 2005, at University of Washington, Bothell.

Estimating Entropy and Entropy Norm on Data Streams

Khanh Do Ba, Dartmouth College, worked with his mentor S. Muthukrishnan, Computer Science, Rutgers University, and another undergraduate, Amit Chakrabarti, on the problem of computing information theoretic functions such as entropy on a data stream, using sublinear space. Their first result deals with a measure they call the "entropy norm" of an input stream: it is closely related to entropy but is structurally similar to the well-studied notion of frequency moments. They developed a polylogarithmic space one-pass algorithm for estimating this norm under certain conditions on the input stream. They also proved a lower bound that rules out such an algorithm if these conditions do not hold. They also developed a sublinear space one-pass algorithm for estimating the empirical entropy of an input stream. For a stream of m items and a given real parameter α, their algorithm uses space very efficiently and provides an approximation of $O(1/\alpha)$ in the worst case and $(1+\varepsilon)$ in "most" cases. All their algorithms have the added benefit of being quite simple.

Complexity of Testing Graph Planarity

Marek Krcal, Charles University, working with mentor, Eric Allender, Computer Science, Rutgers University, came up with a clear and direct proof that testing graph planarity is logspace-reducible to testing planarity for graphs of degree at most 3. This significantly simplifies an argument in a paper of Eric Allender and Meena Mahajan, which in turn relies on a complicated argument of Reif and

Ramachandran, showing that planarity testing is in the complexity class SL. Krcal is writing a paper on this work as part of his Bachelor's thesis and his mentor, Eric Allender, will encourage him to submit it for journal publication.

Experimental Evaluation of Upper Bounds in the Weak Sensor Model

In sensor networks, small devices with processing, sensing and communication capabilities called sensor nodes are randomly deployed over an area in order to achieve sensing tasks after self-organizing as a wireless radio network. Sensor networks can be used in almost any application where sensing or measuring physical variables over large areas is needed, e.g. gathering biological data, sensing in catastrophe areas, etc. Unfortunately, since sensor nodes have strong limitations such as memory size, life cycle and range of communication, the initialization and maintenance of such a network is not a trivial task. Only models that reflect all the various constraints of sensor nodes are adequate to study problems in sensor networks.

Although sensor networks is a very active research area, most of this work is either empirical or includes unrealistic assumptions regarding the capabilities of the sensor nodes. To address these and other issues in sensor networks, a complete model for sensor nodes, called the Weak Sensor Model, was recently developed by Farach-Colton, Fernandes, and Mosteiro. They also provided a protocol for optimal-network bootstrapping, i.e. a protocol for network formation that maximizes life cycle subject to the Weak Sensor Model constraints. Farach-Colton, Fernandes, and Mosteiro gave the first $O(\log^2 n)$ algorithm for constructing the network.

REU/RISE student Andrew Rodriguez, University of Texas at San Antonio, worked with his mentor Martin Farach-Colton, Computer Science, Rutgers University, to evaluate experimentally the performance of the upper bound in the Farach-Colton, Fernandes, and Mosteiro analysis in order to determine if the constants involved in the theoretical analysis are acceptable from a practical point of view. The project was divided in two stages:

1. Experimental evaluation of the sharp power threshold for asymptotic connectivity given in work of Gupta and Kumar.
2. Experimental evaluation of the network formation algorithm given by Farach-Colton, Fernandes, and Mosteiro.

Rodriguez resolved the various implementation issues in order to run the experiments with a reasonably large number of nodes, and he has verified experimentally the sharp threshold of $(\log n + c(n)) / n \rightarrow \pi r^2$, as $n \rightarrow \infty$ (where $c(n)$ is any function such that $c(n) \rightarrow \infty$, as $n \rightarrow \infty$), in the radius of transmission of any node in order to achieve network connectivity. Rodriguez expects to complete the second stage in the future and present these results at a sensor networks conference.

Eulerian Graph Representation for siRNA Sequence Structure

RNAi is a posttranscriptional process that results in the knockout (silencing) of genes through the degradation of mRNAs. Being able to selectively and efficiently silence genes in somatic cells allows for the determination of gene function. In addition, it will hopefully serve as a powerful tool in controlling and understanding disease. Technology using small interfering RNA (siRNA), a naturally occurring oligonucleotide, is being developed in order to further our knowledge of human gene function and disease. A method is needed to distinguish between functional and non functional siRNA sequences.

Karen Lostritto, Brown University, working with her mentor Stan Dunn, Biomedical Engineering, Rutgers University, explored weighted graph models of siRNA sequences to determine which graph properties distinguish between functional and nonfunctional siRNA. She found that the weighted graph structure encompasses important distinctive properties related to siRNA functionality. Therefore properties derived from a graph based model of siRNA show promise for rational design algorithms that will hopefully lead to healthcare applications of RNAi.

Karen Lostritto's poster on this work was a winner in the undergraduate poster session at the Joint Math Meetings, San Antonio, January 12-15, 2006.

Finding a Simple Solution of a Certain Correlation Inequality

Let G be an undirected graph. A subgraph of G is called a forest if it doesn't contain any cycle. Suppose e and f are edges in G. Denote by n, n(e), and n(ef) the number of all forests contained in G, those containing edge e and those containing both edges e and f, respectively. Josef Cibulka and Jan Hladky, Charles University, working with mentor Jeff Kahn, Mathematics, Rutgers University, tried to prove or disprove the conjecture that $n * n(ef) \leq n(e) * n(f)$. This conjecture can be posed for spanning trees instead of spanning forests, but it has already been proven using the theory of electrical networks and recently a combinatorial proof was found as well. Cibulka and Hladky found a new proof that is self-contained and much simpler.

Feature Selection and Error Tolerance for the Logical Analysis of Data

What does it mean for a computer to "learn"? For example, if a computer is given the medical data of a large number of both sick and healthy patients, could it learn to produce a formula for diagnosing future patients as either healthy or sick? Could it tell us what factors are the most important in making that distinction? Previously, doctors diagnosed patients based on a relatively small amount of data: a few test results, experience with former patients, and whatever outside knowledge they had acquired. Now, large laboratory experiments and genetic testing provide us with data that is simply too large for the human brain to analyze. Instead we turn to computers to analyze the data for us. Data such as medical test results are subject to error (perhaps by the humans who conducted the reading, or maybe mechanical estimates). Errors must be allowed for in any formulas created by a computer using this data.

Kathryn Davidson, University of Pennsylvania, and Craig Bowles, Cornell University, worked with their mentor Endre Boros, RUTCOR, Rutgers University, investigating ways for the computer to allow the most error tolerance but create the simplest and most useful formulas for making diagnoses. They developed a new process of analyzing data to determine critical attributes. Their method allows for maximal error tolerance in the original data while producing a choice of simple Boolean formulas for classifying the data. They implemented the method and tested it on the Wisconsin Breast Cancer Database with classification accuracy over ninety percent.

A Discrete Representation of DNA Base Pair Steps

DNA carries genetic information and is usually 2 meters long if one were able to stretch it out. How does it fit into one single cell, which is normally a hundred thousandths of a meter in diameter? The simple answer is it must FOLD tightly. DNA wraps around a protein called Histone forming a primary folding unit nucleosome. However, prior to being transcribed into RNA, the segment of DNA being transcribed must unwind in order for the RNA polymerase to have access to the segment.

Studies have shown that only a small percent of DNA is expressed in any person's lifetime. Thus, how a particular DNA segment folds or how tightly it binds to Histone might dictate how likely it will be expressed.

The traditional approach to studying DNA double helix is to regard it as smooth curves. However, DNA base pair steps are discrete. Thus, a new approach is to understand DNA folding by considering the base pair steps as discrete units.

Yi Lin, Emory University, worked with mentors Wilma Olson and Irwin Tobias, Chemistry, Rutgers University, on a new method for calculating the twist number for a discrete DNA sequence. They found an explicit solution to the integral for the twist number for a segment of any closed DNA with N base pair steps, which saves computing time as well as minimizes computing error. They tested their solution on a few shapes for which the twist numbers were known and their results demonstrate that their new method is valid for calculating twist numbers for closed DNA sequences.

Flight Scheduling: Resolving Conflicts to Reach Optimality

The Pacific oceanic airspace includes flights connecting Australia/New Zealand, Asia, and North America/Hawaii. This airspace alone experiences an average of 700 flights every single day, with little variation throughout the year. Jessica McCoy, North Carolina State University, worked with her mentor Art Chaovalitwongse, Industrial Engineering, Rutgers University, to make enhancements to current scheduling systems, so that flight requests are accommodated with minimal adjustment while maintaining separation regulations of both level and time. The scheduling algorithms attempt to resolve conflicts in flight requests while minimizing the number of track changes, the number of level changes, and the overall departure delays, in that order. The mathematical formulation is a linear programming problem. McCoy and Chaovalitwongse tested different models. Identical data sets of differing sizes were fed into each of the versions, comparing processing time. They found that the processing time skyrockets as more features are added and faster processing comes at the cost of a less realistic model.
But McCoy took a closer look at the section of the algorithms that generated the output and found some errors. She concluded that though the simplest code is fastest, perhaps a new formulation could incorporate some of the complexity of the other versions while maintaining acceptable processing speed.

On the Generation of Short Paths and Minimal Cutsets of the Hierarchical Web Graph

There exist several algorithms that will find a shortest path between two vertices in a graph, for example, Dijkstra's algorithm and Ford's. A more general problem is to find all shortest paths between two vertices. We may also want to find minimal ways to cut the edges in a graph such that all shortest paths between two vertices are removed. This problem has many applications to communications networks. For instance, telecommunications companies are interested in short paths because they provide the most efficient and clear transmissions over a network. An understanding of how many cuts are possible in a network of short paths is important in estimating the reliably of that network. Elizabeth Hayden, Coe College, and Daniel MacDonald, Seton Hall University, working with their mentor Endre Boros, RUTCOR, Rutgers University, developed an efficient algorithm for finding all the shortest paths and an efficient algorithm for finding all minimal sets of edges whose removal cuts all of the shortest paths.

IIC. Training and Development

As noted in the section on Project Activities, the DIMACS/DIMATIA REU program had the following three parts: (i) A group of students from all across the U.S. participated in an 8-week REU program headquartered at DIMACS; (ii) A second group of five students from all across the U.S. participated in the 8-week domestic REU program and then spent 3 additional weeks at DIMATIA; (iii) a group of students from the Czech Republic participated in the 8-week domestic REU program and then acted as hosts at DIMATIA when the U.S. students went to Prague. We collaborated with the Rutgers Department of Mathematics REU program, with participants from the two programs sharing office and living space, attending the same seminars, and participating in shared mentoring activities. We were also affiliated with the Research in Science and Engineering (RISE) program at Rutgers/UMDNJ, sharing two students with that program.

The overall goal of the program was to provide the participants with an exciting research experience that would help them decide on future educational and career paths. All students, including those participating only in the domestic program, got a taste of the international scientific enterprise. The U.S. students going to Prague got a more direct international experience and benefited from the scientific atmosphere at an international center of research, DIMATIA. The Czech students benefited similarly from exposure to their U.S. counterparts and, moreover, contributed to providing the global perspective that we sought. Our REU program is unique because it is run in the context of two major research centers with many scientific activities. The richness of the intellectual community and the international flavor contributed by the many foreign scientists participating in DIMACS and DIMATIA activities at the same time as the REU students added to the overall atmosphere.

The key to our REU program was the one-on-one research experience under the direction of a mentor. The domestic part of the program officially began when the students arrived on the Rutgers campus in mid-June, moved into campus housing (where the students were housed as a group), and received offices and computer and library accounts at DIMACS. They were met by a graduate student coordinator, Lara Pudwell, who organized activities aimed at getting the REU students to meet each other and introduced them to their mentors to begin a program of directed study and research, including regular student/mentor meetings. A welcoming banquet was held, introducing the students to the DIMACS Director and Associate Directors, and orienting them to the many opportunities available to them during the summer. There were a wide variety of research topics that were pursued, including topics in pure mathematics, theoretical computer science, operations research, biomathematics, and homeland security/intelligence. Mentors were from a variety of departments including Chemistry, Biomedical Engineering, School of Communication, Information, and Library Studies (SCILS), RUTCOR, and Industrial Engineering as well as Mathematics and Computer Science. There were computer projects as well as pencil and paper projects. We encouraged and supported lively interactions among students in different projects. Throughout the program, we emphasized applications of discrete mathematics and theoretical computer science. Probably the biggest impact in terms of applications came from topics at the interface between mathematics/computer science and biology. In addition, there was outreach to other mathematical biology research at Rutgers through connections with DIMACS Special Focus on Computational and Mathematical Epidemiology and Special Focus on Information Processing in Biology. The variety of the projects, the interdisciplinary makeup of the mentors, and the social and academic environment all contributed to the breadth of the program.

There were regular lunches and teas, to which all the mentors and students were invited, as well as our weekly DIMACS REU Seminar Series hosting both local speakers and renowned outside speakers. The seminars were preceded by lunch and followed by opportunities to interact with the speaker. One of these seminars was devoted to a presentation about graduate school. Another was a workshop on how to give a presentation. The effectiveness of this workshop was evident from the high quality of the presentations made by the students during the course of the program.

We introduced the students to industrial research by making trips to Telcordia and to IBM Research, where our students participated in tours and technical presentations. Just as we feel it is important for the students to be exposed to multiple (and international) academic environments, we also found that the students were served well by the opportunity to explore two different corporate environments. Students were encouraged to take advantage of all of the activities at DIMACS. Many of them attended talks in biology related DIMACS Workshops such as the ones on Information Processing by Protein Structures in Molecular Recognition, Detecting and Processing Regularities in High Throughput Biological Data, and

Evolutionary Considerations in Vaccine Use or attended the DIMACS Computational and Mathematical Epidemiology Seminar. The 2005 REU program coincided with the DIMACS Bio-Math Connect Institute (BMCI), which provides research experiences for high school teachers and connects them with active researchers in bioinformatics and computational biology. The REU students interacted with both the high school teachers and researchers in BMCI.

Students were asked to make several presentations about their projects during the course of the program. Near the beginning of the program, each student made a presentation describing his or her research problem. These short presentations, made before the entire REU group plus mentors, were aimed at introducing the whole group to the research topics of other members. This encouraged collaboration and discussion and provided the opportunity, as appropriate, to work on multiple projects or even switch projects. One day was spent hosting REU students from Lafayette College. Both the students in the Lafayette REU program and the DIMACS/DIMATIA students made presentations. Near the end of the domestic program, students made short presentations about their work to an audience consisting of REU students, mentors, and others in the DIMACS community. In addition to oral presentations, students were asked to prepare personal websites. These websites describe their problem area and were filled in during the program and after the program ended with results that the students obtained. There was a Farewell Banquet attended by the students, their mentors, the graduate student coordinators, DIMACS Director and Associate Directors. There was a presentation by the Director and awards were given to the students and graduate student coordinators.

The DIMACS part of the program did not end with the end of the DIMACS stay. Our U.S. and Czech REU students have been encouraged to stay in touch with their mentors by email, prepare web pages with their work, and keep those pages up to date after they left. Some of them ended up working on a research paper and/or preparing a presentation at a scientific meeting, still under the guidance of their mentor, after they left DIMACS. Many of our students planned or presented talks at their home institutions and others planned to make their REU project a major piece of their senior thesis or even eventually of a masters thesis.

The goals of the experience in Prague were different from those for the experience in the U.S., and centered on introducing the participating students to a wealth of open problems and questions and appropriate problem-solving techniques and strategies. We did not assign students going to Prague to an individual DIMATIA faculty mentor in advance. Rather, Jarosolav Nesetril, director of DIMATIA, served at first as acting mentor for each of these students. The DIMATIA faculty were involved in mentoring when the students arrived in Prague

Prior to leaving for Prague, students met several times with DIMACS staff to discuss the experience and the logistics. In addition, the Czech REU students and a Czech graduate student coordinator who accompanied the Czech students to DIMACS were available to offer pre-trip advice.

The Prague experience lasted three weeks. The U.S. graduate student coordinator accompanied the group and acted as the liaison person with the DIMATIA faculty and as a program coordinator while in the Czech Republic. The Czech students who participated in the DIMACS REU program in turn acted as hosts for the U.S. students in Prague. In the relatively short time the students were in Prague, they participated in several activities. During the first week, there were several days of special lectures by DIMATIA faculty Jan Kratochvil, Jiri Matousek, and Jaroslav Nesetril on combinatorics, graph theory, and combinatorial geometry to give students another introduction to the scientific interests of the local faculty, to prepare them for the topics of the Twelveth Midsummer Combinatorial Workshop, and to present potential research problems. The students attended talks at the Midsummer Workshop, a traditional problem oriented one-week international workshop on combinatorics, whose speakers included distinguished professors and researchers from leading universities and institutes both in Europe (e.g., Renyi Institute, University of Bordeaux) and the U.S. (Princeton University, Emory University, University of Washington.) After the workshop, a series of small lectures, accompanied by informal discussions by the members of the department at Charles University, widened the knowledge of all the participants of the REU program on various fields of mathematics and computer science. The group meetings emphasized approaches to unsolved problems, problem-solving strategies, and group attacks on problems. Students were encouraged to explore, in collaboration with Czech mentors and students, the research questions that arose during the visit to Prague, either through faculty lectures, the Midsummer Conference, or informal discussions, and to pursue the research project begun at DIMACS with Czech mentors.

Students were met in Prague by the Prague student participants in our domestic program and moved into dormitory housing at Charles University that was provided by DIMATIA (through a companion Czech grant). Funds for meals in Prague were also provided by DIMATIA. There were presentations orienting the students to the culture and history of the city of Prague and the country, with special emphasis on the rich Czech mathematical tradition. The students also took part in various trips organized by Martin Balek, the DIMATIA graduate student coordinator, and the Czech undergraduates who had taken part in the first part of the program at Rutgers.

While the short visit in Prague didn't give students as much time as they had at DIMACS to get deeply into research in pre-defined areas with faculty mentors, the experience taught the students a good deal about how research questions are formulated and pursued. Moreover, with the background gained during the DIMACS portion of the program, the students were able to make a good start on some of the open problems and research topics that they could pursue after leaving Prague. They were encouraged to remain in continuing email contact with their Czech mentors after leaving the Czech Republic.

In a very real sense, the entire project was about training and development, focusing outstanding undergraduates on opportunities in a research career in both academic and business environments and exposing them to the international nature of the research enterprise.

IID. Outreach Activities

As already noted in the section on Training and Development, the 2005 REU program coincided with the DIMACS Bio-Math Connect Institute (BMCI), which provides research experiences for high school teachers and connects them with active researchers in bioinformatics and computational biology. The REU students interacted with the high school teachers in BMCI.

The REU students also interacted with other students at Rutgers University, often to the extent of working on joint projects. REU student Khanh Do Ba, worked with his mentor S. Muthukrishnan, Computer Science, Rutgers University, and undergraduate, Amit Chakrabarti, on the problem of computing information theoretic functions such as entropy on a data stream, using sublinear space. REU/RISE student Andrew Rodriguez's work with his mentor Martin Farach-Colton let to collaboration with graduate student Miguel Mosteiro. Yi Lin worked with mentor Wilma Olson and retiree Irwin Tobias on a new method for calculating the twist number for a discrete DNA sequence.

Some of the REU students have reported being active in additional outreach activities following the summer program.

"I presented my research at the CCSC-NW conference via a poster session. I have also given a talk to the Gonzaga University ACM Chapter to both share what my research was and to promote the REU program to sophomores and juniors at the university. I plan to attend an additional conference in the spring, which potentially may be the SIGCSE conference being held by ACM." Jordanna Chord (REU05)

"I was accepted to Teach for America for the upcoming school year. I also applied for a Fulbright to go abroad for a year, and I hear about that in March. My plan is to start grad school for Biostatistics in Fall 07, but of course since Teach for America is a 2 year commitment, it would be Fall 08 if I chose that route." Alisa Stephens (REU05)

Also of note is the success of REU students in other endeavors. Robert Renaud and Chris Ross were members of the Rutgers team competing in the prestigious 29th Annual World Finals of the Association for Computing Machinery International Collegiate Programming Contest, sponsored by IBM in Shanghai, China. The Rutgers team received Honorable Mention. More than 4,100 teams worldwide entered in the contest's regional competitions leading up to the finals.

III. Journal Publications

E. Boros, V.Gurvich, S. Jaslar (REU02), and D. Krasner (REU02), "Stable matchings in three-sided systems with cyclic preferences," *Discrete Math*, **289** (2005), 1-10.

J. Černý (REU02/03), "Geometric graphs with no three disjoint edges," *Discrete & Computational Geometry*, **34** (2005), 679-696.

J. Černý (REU02/03), J. Kára (REU03), D. Král (REU01/REU04 graduate student coordinator), P. Podbrdský (REU02), R. Šámal (REU03 graduate student organizer), M. Sotakova, "On the number of intersections of polygons," *Commentationes Mathematicae Universitatis Carolinae*, **44** (2003), 217-218.

A. Chakrabarti, K. Do Ba (REU05), and S. Muthukrishnan, "Estimating entropy and entropy norm on data streams," *Internet Mathematics*, to appear.

J. Gevertz (REU04), S. Dunn, and C. Roth, "A mathematical model of real-time PCR efficiency," *Biotechnology and Bioengineering*, **92** (2005), 346-355.

V. Gupta (REU03) and J. Abello, "A collection of realizable chains in the Weak Bruhat Order," in preparation.

V. Jelínek (REU02/03/04), J. Kára (REU01/03), T. Valla (REU03) and R. Šámal (REU03 graduate coordinator), "A winning strategy for the K_4 clique game," in preparation.

D. Král (REU01/REU04 graduate coordinator), J. Maxová, P. Podbrdský (REU02), and R. Sámal (REU03 graduate coordinator), "Pancyclicity of strong products of graph," *Graphs and Combinatorics*, **20** (2004), 91-104.

D. Král (REU01/REU04 graduate coordinator), J. Maxová, P. Podbrdský (REU02), and R. Sámal (REU03 graduate coordinator), "Hamilton cycles in strong products of graphs," *Journal of Graph Theory*, **48** (2005), 299-321.

M.L. Littman, A. Talwar (REU05), M. Zinkevich, "Efficient optimal equilibria in general-sum game trees," in preparation.

M.Y. Tolstorukov, A.V. Colasanti, D. McCandlish (REU03), W.K. Olson, and V.B. Zhurkin, “Superhelical path of nucleosomal DNA is controlled by base-pair slide,” in preparation.

IV. Books or Other One-time Publications

A. Chakrabarti, K. Do Ba (REU05), and S. Muthukrishnan, “Estimating entropy and entropy norm on data streams,” DIMACS Technical Report, 2005-33.

E. Boros and L. Everett (REU04), “Optimal protein encoding,” DIMACS Technical Report 2004-55, November, 2004, updated version under submission.

Z. Dvořák (REU01/02/04), J. Kára (REU03), D. Král (REU01/REU04 graduate student coordinator), O. Pangrác, “On pattern coloring of cycle systems,” *Proceedings 28th International Workshop on Graph-Theoretic Concepts* (WG'02), Lecture Notes in Computer Science, Springer-Verlag, **2573** (2002), 164-175.

Z. Dvořák (REU01/02/04), V. Jelinek (REU02/03/04), D. Král (REU01/REU04 graduate student coordinator), J. Kyncl (REU04), M. Saks, “Three optimal algorithms for balls of three colors,” *Proceedings of 22nd Annual Symposium on Theoretical Aspects of Computer Science* (STACS'05), Lecture Notes in Computer Science, Springer-Verlag, **3404** (2005), 206-217.

V. Website

http://dimacs.rutgers.edu/REU/

VI. Other Products

Presentations

One of the goals of our program was to emphasize student presentations of research. Students returning from our program made presentations in a variety of venues. For instance:

Jordanna Chord (REU05), Melissa Mitchell (REU05), “Entity Resolution for Authors of Biological Sciences Papers,” Seventh Annual Northwestern Regional Conference of the Consortium for Computing Sciences in Colleges, Poster Session, University of Washington, Bothell, October 15, 2005.

Josef Cibulka (REU05), “Correlations in random spanning trees and spanning forests,” Combinatorial Seminar, Charles University, November 25, 2005.

Zdeněk Dvořák (REU01/02/04), Vít Jelínek (REU02/03/04), Daniel Král' (REU01/REU04 graduate student coordinator), Jan Kynčl (REU04), and Michael Saks, “Three optimal algorithms for balls of three colors,” 22nd Symposium on Theoretical Aspects of Computer Science (STACS-05), Stuttgart, Germany, February 24, 2005.

Karen Lostritto (REU05), “Eulerian Graph Representation for siRNA Sequence Structure,” Biomedical Engineering Society Meeting in Baltimore, MD, October 1, 2005.

Karen Lostritto (REU05), "Eulerian Graph Representation for siRNA Sequence Structure," Undergraduate Student Poster Session, Joint Mathematics Meetings, San Antonio Texas, January 14, 2006.

Ross Sowell (REU04), “Multiple Methods and The Federalist Papers,” The Joint Annual Meeting of the Interface and the Classification Society of North America, Washington University School of Medicine, St. Louis, Missouri, June 12, 2005.

Jennifer Staigar (REU05), “Tensor Decomposition of Microarray Data,” Undergraduate Student Poster Session, Joint Mathematics Meetings, San Antonio Texas, January 14, 2006.

Alisa Stephens (RISE/REU05), “The Effect of Selective Sampling Error in Predicting Quality of Care Based on Organizational Attributes,” Annual Biomedical Conference for Minority Students, Atlanta, GA, November 4, 2005.

Michael Y. Tolstorukov, Andrew V. Colasanti, David McCandlish (REU03), Wilma K. Olson, and Victor B. Zhurkin, “Superhelical path of nucleosomal DNA is controlled by base-pair slide,” Fourteenth Conversation in Biomolecular Stereodynamics, Albany, New York, June 14-18, 2005.

Bianca Viray (REU04), and Vladimir Gurvich, “Complete Edge-n-Colored Graphs, Applications and Problems,” DIMACS/DIMATIA/Renyi Working Group on Graph Colorings and their Generalizations II, Prague, Czech Republic, August 2 - 4, 2004.

VII. Contributions within Discipline

VIII. Contributions -- other Disciplines

Throughout the program, we emphasized applications of discrete mathematics and theoretical computer science. Probably the biggest impact in terms of applications came from topics at the interface between mathematics/computer science and biology. This includes the work of University of Pennsylvania undergraduate Kathryn Davidson with mentor Endre Boros (RUTCOR) on machine learning applied to medical diagnoses and the work of Brown University undergraduate Karen Lositritto with mentor Stanley Dunn (Biomedical Engineering) on siRNA sequence structure. Emory University undergraduate Yi Lin worked with mentor Wilma Olson (Chemistry) on DNA folding. Professor Olson's group has been analyzing the known geometry of DNA bases in chemical structures and developing mathematical models to incorporate the sequence-dependent bending, twisting, and translation of known fragments in DNA molecules of varying lengths and chemical composition. In addition, there was outreach to other mathematical biology research at Rutgers through connections with DIMACS Special Focus on Computational and Mathematical Epidemiology and Special Focus on Information Processing in Biology.

X. Contributions -- Human Resource Development

The impact on the careers of our students will take awhile to determine. However, we do have some self-assessment feedback from our recent survey of REU participants. Students who had only a general interest in research now had more focused interests, paths they wanted to immediately pursue. Here are some of the comments we received:

“After participating in RISE/DIMACS I was more encouraged to pursue a PhD rather than a masters. I also learned a lot more about research opportunities available in private industry, which to me made the idea of making a career out of research more appealing than being limited to academia.” Alisa Stephens (RISE/REU05)

“I have found that my participation in the REU program has broadened my perspective on the potential work and diversity of the Machine Learning field. Although I had exposure to work in natural language processing previous to my appointment to Paul Kantor for the REU program, the breadth of my knowledge was limited. After working with the gifted and talented researchers and doctorate students, I was inspired by the shear number of possibilities this research can be applied to.

One of the more enjoyable portions of my work included the group interaction involved in my research project. I appreciated the opportunity to be part of a larger group of talented researchers to work through the many complications of the research we conducted. Coming from a small university, with little diversity, I found working at Rutgers an enlightening experience as the diversity leads to excellent group dynamics and problem solving since the individuals come from such an array of educational and cultural backgrounds.” Jordanna Chord (REU05)

“I thought I should let you know I'm doing my first poster presentation of the work Missy and I completed this last summer while there at Rutgers. The conference is a small regional one the professors of my university attend, so it should be a good ‘first’ for me.” Jordanna Chord (REU05)

“The REU experience definitely changed my life. I realized that although I love math, I am not sure if I want to do purely research for the rest of my life. So I've applied to a variety of graduate programs that use math in another discipline - mainly quantitative psychology. I've also learned to appreciate CS more and have started teaching myself programming languages.” Melissa Mitchell (REU05)

“It's a great program. I just received a thank you card from Jennifer Staigar. In a nutshell, she was very thankful for the opportunity…. Participating in the REU program has definitely shaped her thinking and career path.” Stan Dunn, Mentor

“It changed what I am doing now --- after REU I picked a topic for my B.S. thesis, where the probabilistic method (which I partly learned at Rutgers) is heavily used (I am doing something with random cubic graphs).” Jan Hladky, Charles University (REU05)

“REU had a good impact on me: it gave me an insight into the area of computational complexity that I'll probably study more in the future, and, additionally, my REU work has became a good base for my bachalor thesis. I'm still doing my bachelor thesis on the problem I solved during REU. The title is ‘Reduction of the graph planarity problem to the planarity problem of graphs with maximal degree 3.’” Marek Krcal (REU05)

“I learned about the importance of background research and cross-referencing during the introduction phase of a project. Software output commands are not necessarily infallible, and sometimes what looks like a simpler model on paper will actually generate a more complex programming problem.

In addition to working on my project, I also got to attend the MISTA Conference at the Stern School of Business at NYU. Since Abhinav and I were definitely the only undergraduates in attendance, we learned a lot about scheduling at the thirty+ presentations we went to. Seeing the spread of information at such a focused conference was a nice motivation for research in general; now I have a better idea of how theories and algorithms gain fame and audiences.” Jessica McCoy (REU05)

Managing the REU program also had a positive impact on the graduate student coordinator.

"Personally, this was a positive experience for me. Although I know that I would like to complete a research degree in mathematics, before this summer I was very uncertain whether I would prefer to work for a company (such as Microsoft, IBM, etc.) in their research division or whether I would prefer to work in an academic setting where I can teach. Throughout the program, I found considerable enjoyment working with these talented undergraduates. After this summer, I am slightly less nervous about my first semester as a teaching assistant this fall. The highlight of the program for me was when students would stop by my office and ask my advice or comments about graduate school and the like. I enjoyed that they sought me out just to chat, and it was interesting to me to hear where they were coming from. Overall, my experience as REU coordinator has made me more open to pursuing a teaching career upon completion of my Ph.D." Lara Pudwell

XI. Contributions to Education and Human Resources

XII. Contributions beyond Science and Engineering