International REU 1999–2006
DIMACS and DIMATIA

Preface

DIMACS center of Rutgers University, New Brunswick, and DIMATIA centre of Charles University, Prague, have long standing collaboration spanning more than 10 years.

In 1999 this cooperation got new impulse by establishing an efficient and intensive exchange program for undergraduate students. From the US side this exchange has been funded by NSF within the framework of International REU, and from the Czech side within the Kontakt program of the Ministry of Education of the Czech Republic.

This brief volume reflects the activities of this project which belongs to the star program of both the institutions.

Prague, October 1, 2006

Jaroslav Nešetřil, DIMATIA director

International REU 1999–2006

The program is formed by two parts—one held at the DIMACS center in New Brunswick, NJ, and the other held at the DIMATIA center in Prague, the Czech Republic. About seventeen US undergraduate students take part in the DIMACS part of the program and about five of them also take part in the DIMATIA part of the program. The US students participating in the DIMATIA part are chosen prior to the beginning of the program based on their individual interest in combinatorics and related areas of mathematics. About four or five Czech undergraduate students take part in both the parts of the program each year.

The first part of the program held at the DIMACS center is focused on joint research of students with assigned mentors on specific projects. The Czech students work on several projects with one or two mentors in the area of combinatorics, graph theory or theoretical computer science. The students make two presentations of their projects: at the beginning of the program, they present the topic of their research to other students, and at the end of the program, they show the results achieved during their eight-week work on the projects. In addition, the students also prepare web presentations of their projects. There are also regular lectures (held once or twice a week) on different areas of mathematics given by regular staff as well as visitors of the DIMACS center, Department of Mathematics and Department of Computer Science of the Rutgers University. In this way, the students got exposed to different branchces of mathematics and computer science. Some of the students visiting Prague also present their projects during the Midsummer Combinatorial Workshop, the conference held during the course of the DIMATIA part of the program.

The Czech part of the program lasts about three weeks. The US students attend an informal introduction to life and culture of the Czech Republic before their departure. The introduction is given by the Czech students taking part in the program. The Czech students also act as hosts of the US students in Prague—they meet them at the airport and take care of their stay in Prague, visit with them different landmarks during weekends, etc.

A regular part of the program is formed by Midsummer Combinatorial Workshop—the workshop is held the first week in August since 1993, time that coincides with the first week of the stay of US students in Prague. Some of the students are also asked to present their results during the workshop.

After the workshop, the students attend lectures that introduce to them to different areas of combinatorics, graph theory, algorithms etc. In the past, the lectures were given by Jiří Fiala, John Gimbel, Daniel Král', Martin Klazar, Petr Kolman, Jan Kratochvíl, Martin Loebl, Jiří Matoušek, Martin Mareš, Jaroslav Nešetřil and Pavel Valtr. The students work on small projects under the supervision of the lecturers but they are not preassigned to individual DIMATIA mentors before they arrive to Prague. The lectures are also attended by other international students visiting the DIMATIA center in Prague, e.g., four undergraduate students from Slovenia attended the lectures this year.

The stay of US students in Prague is not only full of scientific activites but they are also exposed to a lot of cultural and social activities, some of them being part of Midsummer Combinatorial Workshop, some of them especially prepared for the US students. As an example let us mention a tour through the exposition of modern art of the Czech National Gallery guided by professor Nešetřil himself. Walks through Prague as well as trips to Kutná Hora (UNESCO heritage site) or the castles of Karlštejn, Konopiště or Křivoklát appear on the list of activities almost each year.

There are several papers written by Czech and US students based on their experience during the program. Let us point out the paper "An Algorithm for Cyclic Edge Connectivity of Cubic Graphs" by Z. Dvořák, J. Kára, D. Král', O. Pangrác (participants of REU 2001) that was awarded the Best Student Paper Award at 9th Scandinavian Workshop on Algorithm Theory held in Humlebeak, Denmark.

List of participants

1999

US mentor at DIMACS:
János Komlós
Czech mentors at DIMATIA:
Jan Kratochvíl
Jiří Matoušek
Jaroslav Nešetřil
Pavel Valtr
Czech graduate coordinator:
Jana Maxová
Czech students:
Robert Šámal
Jan Vondrák
US graduate coordinator:
Paul Dreyer
US students visiting Prague:
Jessica Kazimir *(Montclair State University)*
Carly Klivans *(MIT)*
David Kravitz *(University of Delaware)*
Tanzy Mae Tallapoose Love
(California State University at Hayward)
Christopher Malon *(University of Chicago)*

2000

US mentor at DIMACS:
Endré Szemerédi
Czech mentors at DIMATIA:
Martin Klazar
Jan Kratochvíl
Jiří Matoušek
Jaroslav Nešetřil
Pavel Valtr
Czech graduate coordinator:
Jana Maxová
Czech students:
Daniel Král'
Pavel Podbrdský
Robert Šámal
US graduate coordinator:
Laura Ciobanu
US students visiting Prague:
Ricardo Collado *(University of Puerto Rico)*
Robert Sidney Cox III
(New College of Univ. of South Fla.)
Jean Griffin *(Rutgers University)*
Stephen Marotta *(Drew University)*
Ryan Williams *(Cornell University)*

2001

US mentor at DIMACS:
Jeff Kahn
Czech mentors at DIMATIA:
Martin Klazar
Jan Kratochvíl
Martin Loebl
Jaroslav Nešetřil
Pavel Valtr
Czech graduate coordinator:
Ondřej Pangrác
Czech students:
Zdeněk Dvořák
Jan Kára
Daniel Král'
US graduate coordinator:
Cliff Smyth
US students visiting Prague:
Ioana Gradinaru *(Harvard College)*
Daniel Krasner *(University of California at Berkeley)*
Karen Lange *(Swarthmore College)*
Tim Mitchell *(Tufts University)*
Michael Picollelli *(University of Delaware)*

2002

US mentor at DIMACS:
János Komlós
Czech mentors at DIMATIA:
Jiří Fiala
Jan Kratochvíl
Martin Loebl
Jiří Matoušek
Jaroslav Nešetřil
Pavel Valtr
Czech graduate coordinator:
Martin Mareš
Czech students:
Jakub Černý
Zdeněk Dvořák
Vít Jelínek
Pavel Podbrdský
US graduate coordinator:
José B. Torres
US students visiting Prague:
Paul Gross *(Rose-Hulman Institute of Technology)*
Steven Jaslar *(Rutgers University)*
Daniel Krasner *(University of California at Berkeley)*
Yuki Saka *(University of California at Berkeley)*
Ursula Whitcher *(Swarthmore College)*

2003

US mentor at DIMACS:
Jozsef Beck
Czech mentors at DIMATIA:
Jiří Fiala
Martin Klazar
Jan Kratochvíl
Jiří Matoušek
Jaroslav Nešetřil
Pavel Valtr
Czech graduate coordinator:
Robert Šámal
Czech students:
Jakub Černý
Vít Jelínek
Jan Kára
Aleš Přívětivý
Ida Švejdarová
Tomáš Valla
US graduate coordinator:
José B. Torres
US students visiting Prague:
Michael Grabchak *(Rutgers University)*
Vishal Gupta *(Yale University)*
Victor Kostyuk *(Rochester Institute of Technology)*
Alexander Olshevsky *(Georgia Institute of Technology)*
Tatiana Yarmola *(University of California at Berkeley)*

2004

US mentors at DIMACS:

Michael Saks
Alexander Soifer

Czech mentors at DIMATIA:

Jiří Fiala
Petr Kolman
Martin Klazar
Jan Kratochvíl
Jaroslav Nešetřil
Pavel Valtr

Czech graduate coordinator:

Daniel Král'

Czech students:

Zdeněk Dvořák
Vít Jelínek
Jan Kynčl
Eva Ondráčková
Tomáš Valla

US graduate coordinator:

Sarah Genoway

US students visiting Prague:

Shiri Azenkot *(Pomona College)*
Logan Everett *(Binghamton University)*
Tracy Grauman *(Rutgers University)*
Diana Michalek *(University of California at Berkeley)*
Bianca Viray *(University of Maryland)*

2005

US mentors at DIMACS:

Eric Allender
Jeff Kahn

Czech mentors at DIMATIA:

John Gimbel
Petr Kolman
Jan Kratochvíl
Martin Loebl
Martin Mareš
Jaroslav Nešetřil
Pavel Valtr

Czech graduate coordinator:

Martin Bálek

Czech students:

Josef Cibulka
Jan Hladký
Marek Krčál

US graduate coordinator:

Lara Pudwell

US students visiting Prague:

Sarah Bleiler *(Seton Hall University)*
Craig Bowles *(Cornell University)*
Melissa Mitchell *(University of Detroit—Mercy)*
Samuel Nelson *(Bucknell University)*
Arjun Talwar *(Stanford University)*

2006

US mentors at DIMACS:

Radoš Radoičič
Mario Szegedy

Czech mentors at DIMATIA:

Jiří Fiala
John Gimbel
Petr Kolman
Daniel Kráľ
Jan Kratochvíl
Martin Mareš
Jiří Matoušek
Jaroslav Nešetřil
Pavel Valtr

Czech graduate coordinator:

Vít Jelínek

Czech students:

Josef Cibulka
Jan Hladký
Alexandr Kazda
Bernard Lidický
Eva Ondráčková
Martin Tancer

US graduate coordinator:

Lara Pudwell

US students visiting Prague:

Natalia Cordova *(University of Puerto Rico)*
Elizabeth Gillaspy *(Macalester College)*
Kelsey Livingston *(Smith College)*
Megan Olson *(Winona State University)*
Benjamin Sowell *(Carleton College)*
Alex Waldron *(Harvard University)*

Czech participants

Martin Bálek	master degree in 2002, PhD student of Charles University
Jakub Černý	master degree in 2003 from Charles University, PhD student at Charles University since 2003, Mitsubishi Research internship 2005
Josef Cibulka	undergraduate student of Charles University
Zdeněk Dvořák	master degree in 2004 from Charles University, PhD student at Charles University since 2004
Jan Hladký	bachelor degree in 2006 from Charles University, master student at Charles University since 2006, internship at ETH Zurich 2006
Vít Jelínek	master degree in 2004 from Charles University, PhD student at Charles University since 2004
Jan Kára	master degree in 2003 from Charles University, PhD student of Charles University since 2003, student fellowship 2004/05 at Humboldt University in Berlin, Mitsubishi Research internship 2006
Alexandr Kazda	undergraduate student of Charles University
Daniel Král'	master degree in 2001 and PhD degree in 2004 from Charles University, postdoc 2004/05 at TU Berlin, Germany, postdoc 2005/06 at Georgia Institute of Technology, Atlanta, GA, assistant professor at Charles University since 2006
Marek Krčál	bachelor degree in 2006 from Charles University, master student at Charles University since 2006
Jan Kynčl	master degree in 2006 from Charles University, PhD student of Charles University since 2006
Bernard Lidický	undergraduate student of Charles University
Martin Mareš	master degree in 2001, PhD student of Charles University
Eva Ondráčková	master degree in 2006 from Charles University, PhD student of Charles University since 2006
Ondřej Pangrác	master degree in 2000 and PhD degree in 2004 from Charles University, assistant professor at Charles University since 2004

Pavel Podbrdský	master degree in 2004 from Charles University, Marie Curie Training Programme at University College London in winter term 2004/05, currently PhD student at Charles University
Aleš Přívětivý	master degree in 2003 from Charles University, PhD student of Charles University since 2003
Robert Šámal	master degree in 2001 and PhD degree in 2006 from Charles University, postdoc 2006/07 at Simon Fraser University, Vancouver, BC
Ida Švejdarová	bachelor degree in 2003 from Charles University, PhD student at University of Illinois, Urbana-Champaign
Martin Tancer	undergraduate student of Charles University, internship at University of Ljubljana 2005
Tomáš Valla	master degree in 2006 from Charles University, PhD student at Charles University since 2006
Jan Vondrák	bachelor degree in 1995 from Charles University (major physics), master degree in 1999 from Charles University (major computer science), PhD degree from MIT in 2004 (applied math), postdoc at MSRI, Berkeley in Spring 2005, postdoc at Microsoft Research in 2005/06, teaching fellow at Princenton University since 2006

Abstracts of papers based on results from REU

P. A. Dreyer, C. Malon, J.Nešetřil
Universal H-colorable graphs without a given configuration
Discrete Mathematics 250(1–3) (2002), 245–252.
[stemming from REU 1999]

For every pair of finite connected graphs F and H, and every integer k, we construct a universal graph U with the following properties:

1. There is a homomorphism $\pi : U \to H$, but no homomorphism from F to U.
2. For every graph G with maximal degree no more than k having a homomorphism $h : G \to H$, but no homomorphism from F to G, there is a homomorphism $\alpha : G \to U$, such that $h = \pi \circ \alpha$.

Particularly, this solves a problem asked by Galluccio, Hell and Nešetřil regarding the chromatic number of a universal graph.

D. Kráľ, J. Maxová, P. Podbrdský, R. Šámal
Pancyclicity of Strong Products of Graphs
Graphs and Combinatorics 20(1) (2004), 91–104.
[stemming from REU 2000]

We prove that the strong product of graphs $G_1 \times \cdots \times G_n$ is pancyclic, in particular hamiltonian, for $n = c \cdot \Delta$ for any $c > \ln(25/12) + 1/64$ (approximately 0.75) whenever all G_i are connected graphs with the maximum degree at most Δ.

D. Král', J. Maxová, P. Podbrdský, R. Šámal
Hamilton Cycles in Strong Products of Graphs
Journal of Graph Theory 48(4) (2005), 299–321.
[stemming from REU 2000]

We prove that the strong product of any n connected graphs of maximum degree at most n contains a Hamilton cycle. In particular, $G^{\Delta(G)}$ is hamiltonian for each connected graph G which answers in affirmative a conjecture of Bermond, Germa and Heydemann.

Z. Dvořák, J. Kára, D. Král', O. Pangrác
On Pattern Coloring of Cycle Systems
Proceedings 28th International Workshop on Graph-Theoretic Concepts (WG'02), Lecture Notes in Computer Science vol. 2573, pp. 164–175, Springer-Verlag, 2002.
[stemming from REU 2001]

A k-cycle system is a system of cyclically ordered k-tuples of a finite set. A pattern is a sequence of letters. A coloring of a k-cycle system with respect to a set of patterns of length k is proper iff each cycle is colored consistently with one of the patterns, i.e. the same/distinct letters correspond to (the) same/distinct color(s). The feasible set of a cycle system is the set of all ℓ's such that there exists a proper coloring of it using exactly ℓ colors.

For all combinations of a pattern set Π and a number ℓ, we either find a polynomial algorithm or prove NP-completeness of the problem whether a given cycle system with a set of patterns Π can be colored by at most ℓ colors. We further construct a cycle system with a prescribed feasible set for almost every set of patterns containing only two different letters.

Z. Dvořák, J. Kára, D. Kráľ, O. Pangrác
An Algorithm for Cyclic Edge Connectivity of Cubic Graphs
Proceedings 9th Scandinavian Workshop on Algorithm Theory (SWAT'04), Lecture Notes in Computer Science vol. 3111, pp. 236–247, Springer-Verlag, 2004.
[stemming from REU 2001]

The cyclic edge connectivity is the size of the smallest edge cut in a graph such that at least two of the parts of the graph are not acyclic. We present an algorithm running in time $O(n^2 log^2 n)$ for computing the cyclic edge connectivity of n-vertex cubic graphs.

Z. Dvořák, J. Kára, D. Kráľ, O. Pangrác
Feasible Sets of Pattern Hypergraphs
submitted for publication, available as ITI report 2002–093
[stemming from REU 2001]

The notion of pattern hypergraph provides a unified view of several previously studied coloring concepts. A pattern hypergraph H is a hypergraph where each edge is assigned a type P_i that determines which of possible colorings of the edge are proper. A vertex coloring of H is proper if it is proper for every edge. In general, the set of integers k such that H can be properly colored with exactly k colors need not be an interval. We find a simple sufficient and necessary condition on the edge types $P_1, \dots, P_k$ for the existence of a pattern hypergraph H with edges of types $P_1, \dots, P_k$ such that the numbers of colors in proper colorings of H do not form an interval of integers. Our results also have consequences for testing optimality of solutions of constraint satisfaction problems.

J. Černý, Z. Dvořák, V. Jelínek, P. Podbrdský

Generalization of the polygon-crossing problem

submitted for publication, available as KAM-DIMATIA Series 2003–632.

[stemming from REU 2002]

We study the maximum possible number of intersections of a simple k-gon with a simple ℓ-gon for $k, \ell \geq 3$ odd. We generalize this problem to a larger class of objects. We prove that the number of intersections cannot exceed $k\ell - k - (\ell - 3)/2$. This improves the best known upper bound and gives alternative solution of the case $\ell = 5$.

Z. Dvořák, V. Jelínek, D. Král', J. Kynčl, 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 vol. 3404, pp. 206–217, Springer-Verlag, 2005.

[stemming from REU 2004]

We consider a game played by two players, Paul and Carol. Carol fixes a coloring of n balls with three colors. At each step, Paul chooses a pair of balls and asks Carol whether the balls have the same color. Carol truthfully answers yes or no. In the Plurality problem, Paul wants to find a ball with the most common color. In the Partition problem, Paul wants to partition the balls according to their colors. He wants to ask Carol the least number of questions to reach his goal. We find optimal deterministic and probabilistic strategies for the Partition problem and an asymptotically optimal probabilistic strategy for the Plurality problem.

Z. Dvořák, V. Jelínek, D. Král', J. Kynčl, M. Saks
Probabilistic Strategies for the Partition and Plurality Problems
accepted for publication in Random Structures and Algorithms.
[stemming from REU 2004]

We consider a game played by two players, Paul and Carol. Carol fixes a coloring of n balls with three colors. At each step, Paul chooses a pair of balls and asks Carol whether the balls have the same color. Carol truthfully answers yes or no. In the Plurality problem, Paul wants to find a ball with the most common color. In the Partition problem, Paul wants to partition the ballsaccording to their colors. Paul's goal is to ask Carol the least number of questions to reach his goal. We find optimal probabilistic strategies for the Partition problem and the Plurality problem in the considered setting.

J. Cibulka, J. Hladký
A correlation inequality for spanning trees in a graph
in preparation.
[stemming from REU 2005]

We give a self-contained proof of the following statement: Let G be a connected graph, let e and f be two its edges. Let T be its spanning tree chosen uniformly at random. Then $\Pr[T \text{ contains } e] \geq \Pr[T \text{ contains } e|T \text{ contains } f]$. The fact was already known from the theory of electrical networks.

M. Krčál
Planarity is SL-reducible to planarity of max-degree-three graphs
in preparation.
[stemming from REU 2005]

We will give the second proof that the problem of planarity testing is in SL (symmetric nondeterministic LOGSPACE). It will be done by showing a reduction of the problem to planarity of graphs with maximal degree three. Note that usual replacing vertices of degree bigger than three by "little circles" can spoil planarity, we need to be smarter. Planarity of graphs with maximal degree three was already solved in paper "Symmetric complementation" by John Reif.

Our approach is very different and more intuitive than the one in the first proof by Meena Mahajan and Eric Allender ("Complexity of planarity testing"), which is pure SL implementation of a very complicated parallel algorithm by John Reif.

This result together with recent breakthrough by Omer Reingold that SL=L ("Undirected ST-connectivity in log-space") completely solves the question of complexity of planarity problem, because planarity is hard for L (it is again shown in "Complexity of planarity testing").

Bernard Lidický, Martin Tancer
A note on 3-choosability of planar graphs
in preparation.
[stemming from REU 2006]

We prove that a planar graph without a triangle, a cycle of length five, and a pair of four-cycles sharing an edge is 3-choosable. This result strengthens the results of Lam, Shiu and Song. Our proof is based on a discharging argument. Apart from that, we present a new example of a triangle-free non-3-choosable graph, which is smaller than previously known example due to Voigt.

Presentations of REU students at Midsummer Combinatorial Workshops

Midsummer Combinatorial Workshop 2000
Daniel Král'
On hamiltonian cycles in strong products of graphs

Midsummer Combinatorial Workshop 2001
Daniel Krasner
On convex polytopes in the plane "containing" and "avoiding" zero

Midsummer Combinatorial Workshop 2002
Daniel Krasner
Stable matchings in three-sided systems with cyclic preferences

Midsummer Combinatorial Workshop 2002
Pavel Podbrdský
Generalization of the polygon-crossing problem

Midsummer Combinatorial Workshop 2004
Zdeněk Dvořák
Three optimal algorithsm for balls of three colors