Foreword

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On August 5, 2006 our community suffered a great loss. Misha Alekhnovich, one of its brightest and most prominent young members, tragically died in a white-water rafting accident in Russia at age 27. This happened in an expedition along the Chulymshan river (Altai region, Siberia) led by Konstantin Vasin. The Russian-speaking reader can read different accounts of this trip in http://www.whitewater.ru/doc.php?2006-Chulyshman-otchet and http://www.whitewater.ru/forum/messages/35523.html.

This untimely death has put an end to what started, and doubtlessly would have continued, as an exceptionally bright and promising career in our field. The community reacted to the event in a number of appropriate ways, including a special session devoted to Misha's memory at the BIRS Workshop on Recent Advances in Computational Complexity and an obituary in SIGACT News (38(1), 2007). After the initial shock was gone, however, and the sad news finally sank in, we began thinking of what we could do to preserve Misha's memory in the long run.

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What really remains on earth from people of our profession are our students and our results and ideas, with their material incarnation in the form of books and papers. Misha was too young to have students and that also ruled out books. We searched through his archives; it was absolutely clear from what we saw that Misha was extremely full of novel and bright ideas at the time of his death. But we have not found anything sufficiently well-organized that we could assume the responsibility to make Misha's thoughts public without having the opportunity to ask Misha's own opinion about this. Thus, after considerable hesitation and deliberations, we have simply set the goal to make sure that all papers in conference proceedings authored or co-authored by Misha are properly reviewed and published in scientific journals.

We are glad to report that the current volume, to the best of our knowledge, accomplishes this mission (see Misha's bibliography at the end of this foreword). The choice of the journal was quite natural: 15 years ago, *Computational Complexity* already set the important precedent of commemorating the memory of exceptionally talented people in our community having passed away at a young age by publishing a special issue devoted to Roman Smolensky (Vol. 6, No 3/4, 1996).

While we certainly do not attempt to decline our own responsibility for the delay of this publication, we would like to note that a few papers in this issue did require a significant amount of work (in one case we did not even have a TeX source). This would be impossible without help generously provided by many people; we will properly and gratefully acknowledge this help below.

The first article in this issue is an obituary written by Misha's closest friends as a collection of personal memories about him. It is both unnecessary and impossible for us to compete with it here, but we would like to add to this obituary a few words describing Misha's personality from a more professional side. But these are personal memories all the same, and to stress this fact, the next few paragraphs are written in the first person, with the narrator being indicated at the beginning.

Alexander Razborov: I was Misha's supervisor during his undergraduate years at Moscow State University. I first met Misha in the late winter of 1997 when he came to my office to discuss the possibility of doing research in our area. I tried to give him an introductory lecture about **P** vs. **NP** and, strangely, I do not remember a single concrete question asked by Misha. What I do remember quite vividly, though, is that the venerable

"knowledgeable prof. vs. ignorant but respectful and attentive student" was shattered to pieces during the first nine minutes of our acquaintance, and it never came back during those nine years that I was privileged to know Misha. He asked questions that took several minutes to answer. He asked questions that I had to look up in the literature after our meeting. He immediately grasped the general idea of what and why we are trying to do in this area and started to offer directions and approaches. They were sometimes naive but never, never silly. I was so much impressed by Misha's intuition, insight and speed that I was very glad when he chose me as his advisor. This gave me the wonderful gift of nine years of interaction with one of the most creative, independent and quick minds I ever met in my life. This interaction took very different forms: from the finest technical details in writing our joint papers to very abstract discussions on topics very loosely related to mathematics or computer science. But the content was always similar: Misha did possess the ability to see things in an unexpected light and was very much open to (and often took visible pleasure in) constructive debates on any imaginable subject. And at the same time he always stuck to what in his opinion was right and never compromised on issues he considered important: you could sway his opinion but not change his stance.

Toni Pitassi: I first came to know of Misha 1997. I had been working on an impossibility result together with Shlomo Moran, and we had managed to prove NP-hardness of searching for short propositional proofs. We had a draft of our paper, and at some point mentioned our results to Sam Buss. Sam told me that he had recently heard that very similar results had been obtained by an undergraduate in Moscow! A few days later, we received a short draft by Misha. It contained all of the essential ideas of our impossibility result, and then went beyond!

This was the first of many times where I witnessed Misha's brilliance. Another time, I was working with Jan Johannsen and Alasdair Urquhart, to prove a separation between regular Resolution and general Resolution. We had managed to find a complicated family of tautologies, as well as a long and involved proof that these tautologies had short Resolution proofs, but required very large regular Resolution proofs. Once again, enter Misha. He sent us a two page draft. The paper contained a very different set of examples, expertly and insightfully crafted to possess just the right properties required to give a clean and simple argument.

In the years that followed, we became collaborators, and worked on many research problems together. Misha always brought deep insight, creating beautiful solutions that could be reused in many contexts. It was a delight to receive one of his signature one-page emails (that sometimes took months

or years to digest), that came long before the finished manuscript. I became friends with Misha, and we had many laughs together. He was intense about mathematics, but lighthearted in spirit. He loved the outdoors and it was a pure joy to be in his company. I will miss his unforgettable smile.

Madhu Sudan: I met Misha first a few months before he joined MIT. I had heard of his works in proof complexity even before. In fact I was aware Misha had given a few talks at MIT before, but I had missed them since I was out of town. When we were first introduced, he told me he was coming to MIT's Mathematics Department in a few months - I congratulated him and expressed the wish that we would have ocassion to chat and inquired if he was to an Instructor (a pre-tenure teaching position) or on tenure-track. Misha corrected me quickly telling me he was going to start as a Ph.D. student. This came as a big surprise to me, but I got over it. During his first year at MIT, Misha sat in on a few of my lectures on coding theory, but seemed to find the pace too slow and soon stopped coming to lectures. But he would drop by my office looking for new challenges. I was happy to see him continue to work on proof complexity, but he wanted to prove he could go beyond, so I described a problem whose solution would lead to a near-linear time algorithm for some problem in coding theory. Within a week he had resolved the question and really developed a nice language (if not theory) in which the question and answer seem to flow much more naturally (see [9]). This led to more regular visits to my office where Misha would explain what he was up to and I would try my best to keep pace with him. Until about the middle of his second year he had not yet chosen a supervisor. I defaulted into this role due to our frequent conversations, though it was clear Misha had no need for supervision. On technical matters, he was always quicker than me; and on matters of life he seemed to know what he wanted and the best way to get there. It came only as a mild surprise when he announced his wish to graduate by the end of his second year (which must be very rare at MIT - I don't know of another such case). But after talking to him a bit, it was clear he did know what he was doing, and so we agreed on his plan and implemented it. Despite the short duration of our interactions, Misha managed to leave a deep impression on me. His work, to the extent I understood it, was characterized by simple but powerful conceptual observations which was back up by as much technical strength as required. I was fortunate to be around him for the two years that I was, so he could reveal the simple parts to me, which were often obscured in the publications due to the technical parts. It would be fair to say I learned more from him than the other way during our interactions.

Samuel Buss and Russell Impagliazzo: Misha Alekhnovich spent only

one year in San Diego, Fall 2005 through Spring 2006; however, he had already had a substantial influence on us before that. One of us (Sam) was first contacted by Misha via an introduction by Alexander Razborov in late October 1997. Sam describes this as follows: "At the time, Misha was working as undergraduate in Moscow and had been successful in proving some results on the hardness of k-provability. I was able to make a small improvement to his result and we started to write the paper jointly, joined later by Shlomo Moran and Toni Pitassi. This paper ([1]) was purely a long-distance collaboration, and I only met Misha some years later in 2001. From the very beginning of our collaboration, I was highly impressed by Misha's contributions, and I distinctly recall feeling that his contributions to the paper had been particularly fundamental. Certainly, his contributions were far beyond those of an undergraduate student; indeed, they were already even then at the level of a strong, established researcher." We long considered Misha one of the most technically powerful and innovative researchers in proof complexity and indeed all of computational complexity.

We felt privileged when Misha moved to San Diego in Fall 2005, but tragically he spent less than one year in San Diego. On his interview visit to UCSD, he began a research conversation with one of us (Russell) on a new direction Russell was exploring with several other researchers, to show limits on the power of back-tracking and dynamic programming. During that conversation, Misha showed how techniques he had developed with Hirsch could be used in that context to dramatically improve the lower bounds to stronger versions of the model. Russell and Misha continued working on that project over the years, and had a meeting planned to discuss the journal version when he returned from his vacation in Russia. Unfortunately, that meeting never took place. The journal version was eventually completed, and appears in this volume ([15]).

Misha was an idealistic person and an excellent colleague. We did not actually get to spend that much time with him socially in San Diego. However, one of us (Russell) had the opportunity to get to know him somewhat better during a workshop in Cambridge shortly before his death. The workshop included a punting excursion; Misha proved to be very comfortable with boats and took complete charge of the punting. Misha seemed to enjoy living in San Diego and made a number of new friends. He was adjusting to university-level teaching and working on a range of research projects. Misha did not tell us much about his ongoing research, but during the last half year in San Diego, he gave indications that he was achieving some strong results. If so, however, they seem to be lost.

Misha's untimely death was a real tragedy. We both continue to feel a

strong sense of loss, on both personal and scientific levels.

We conclude with a brief introduction to the papers appearing in this volume.

Misha began his research career in Propositional Proof Complexity and, despite his young age, very quickly became one of the leading experts in the area. This development was greatly facilitated by his participation in the Special Year on Complexity Theory at IAS, Princeton (2000-01). That prominent event had a very strong proof complexity component, and Misha was able to communicate (and communicate as an equal!) with some of the very best minds in the area. In our special issue, Misha's research in "pure" proof complexity is represented by the paper [14]. One ultimate test for our understanding of the power of a proof system is given by our ability to prove that random CNFs are hard for the k-DNF resolution system. Except for "natural curiosity", one pragmatic (and largely empirical) reason is that such results usually turn out to be more universal, and the methods can be normally applied in a variety of other interesting situations. The main contribution of [14] is defined simply: that paper proves exponential bounds for random CNFs for the system $Res(k)$ (operating with k-CNFs for an arbitrary fixed k). Despite several years that have elapsed since the publication of the conference version of [14], this result remains unsurpassed, and $Res(k)$ is still the strongest proof system for which this is known.

Misha was constantly looking to expand his horizons and apply to other areas his ideas and experience gained in proof complexity. His PhD years (MIT, 2001-03) were particularly beneficial for him in this respect. In our issue, this "transitional" period is well represented by several papers.

The first of them, [16], is devoted to the study of LP and SDP relaxations of 0-1 optimization problems. Questions of this sort are among the most interesting and actively studied in both algorithmic and complexity communities, and of particular interest here are *systematic* procedures like Lovász-Schrijver, as opposed to particular ad hoc relaxation schemes tailored to individual problems. As is well known these days, questions of this kind allow a neat proof-complexity reformulation and many techniques and paradigms from proof complexity (like the use of expansion) turn out to be extremely useful in tackling hem. This realization, however, was not always a part of the landscape and as early as a few years ago the two communities were almost completely separated. Paper [16] was one of the very first to exploit this connection, and it was used there to prove strong concrete bounds on the approximation ratio for some well-known problems.

The next paper in this series, [8], was originally motivated by the question whether the system of Resolution is quasi-automatizable, i.e., if there is a proof-searching algorithm for this system with the running time that is quasi-polynomial in the size of the shortest Resolution proof. Another paper written around the same time, [5] proved that such an algorithm with *polynomial* time performance may not exist modulo a plausible assumption from parameterized complexity, and indicated that the question of quasi-automatizability is intimately related to some subtle relations between Resolution proof size and width. Motivated by this quest, [8] proposes a new proof search heuristics that works particularly well for CNF with small branch-width of the underlying hypergraph and analyzes performance of this algorithm on the class of Tseitin tautologies.

The next paper [15] in this issue is another reflection of Misha's expanding horizons. Similar in spirit to [16], the goal in [15] is to study the limitations of a class of search and optimization algorithms. Namely, the focus of this paper is on basic variants of dynmic programming and backtracking algorithms. Once again, incorporating ideas from proof complexity, amongst other results it is shown that 3-SAT requires exponential complexity in this precisely defined class of algorithms.

Paper [17] establishes the strongest inapproximability results known to date for the closest vector problem with preprocessing (CVPP) and the analogous problem for linear codes yielding significant progress over previous work. Specifically, the paper proves the first non constant NP-hardness result for the approximation version. Previous work only proved NP-hardness for some specific constant factor ($\sqrt{3}$ for CVPP in Euclidean norm).

The last paper in this issue [11] is devoted to exploiting connections between "crypto-style" average case complexity and the theory of approximation algorithms. It proposes an interesting new model combining features of average-case and worst-case complexities and introduces in this framework several bold assumptions about the cryptographic hardness of certain problems associated with decoding linear codes. Implications of these assumptions to the complexity of approximating several well-studied problems are striking, and partly due to this reason, this paper generated quite a considerable interest in both communities.

Acknowledgment

This project would be unthinkable without a helping hand generously provided by many people. To name just a few, Sam Buss, Max Nalsky and

Alexandra Arkhipova managed to locate Misha's electronic archives, and Sanjeev Arora greatly helped us in evaluating them. Our special thanks are due to Benny Applebaum for the enormous amount of time and energy invested in bring the style of presentation in [11] much closer to journal standards. We are thankful to Eli Ben-Sasson and Valentine Kabanets for several useful discussions. We are grateful to Joachim von zur Gathen for providing this possibility to commemorate Misha's memory and for his infinite patience in coping with various delays we have caused. Last, but definitely not the least, we are grateful to anonymous referees of all papers appearing in this issue.

A Professional Biography

The full version is available from Misha's CV at http://www.math.ias.edu/~misha/cv.html.

Fall 1995-2000 Student in Department of Mathematics and Mechanics, Moscow State University

Degree awarded Diploma with Honors (B.A. equivalent)

Diploma thesis Pseudorandom generators in Propositional Proof Complexity

Thesis Supervisor Prof. Alexander Razborov

Fall 2000-2001 Member in the special program on Computational Complexity, Institute for Advanced Study (host Prof. Avi Wigderson)

Fall 2001-2003 Graduate student in Department of Mathematics, MIT

Degree awarded Ph.D. of Science (Applied Mathematics and Computer Science)

Diploma thesis Propositional Proof Systems: Efficiency and Automatizability

Thesis Supervisor Prof. Madhu Sudan

Fall 2003-2005 Member, Institute for Advanced Study (host Prof. Avi Wigderson)

Fall 2005-2006 Assistant Professor, Department of Mathematics at UCSD.

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References

[1] M. Alekhnovich, S. Buss, S. Moran, and T. Pitassi. Minimum propositional proof length is NP-hard to linearly approximate. *Journal of Symbolic Logic*, 66:171–191, 2001.

[2] M. Alekhnovich, E. Ben-Sasson, A. Razborov, and A. Wigderson. Space complexity in propositional calculus. *SIAM Journal on Computing*, 31(4):1184–1211, 2002.

[3] M. Alekhnovich, E. Ben-Sasson, A. Razborov, and A. Wigderson. Pseudorandom generators in propositional proof complexity. *SIAM Journal on Computing*, 34(1):67–88, 2004.

[4] M. Alekhnovich. Mutilated chessboard problem is exponentially hard for resolution. *Theoretical Computer Science*, 310(1-3):513–525, 2004.

[5] M. Alekhnovich and A. Razborov. Resolution is not automatizable unless $W[P]$ is tractable. *SIAM Journal on Computing*, 38(4):1347–1363, 2008.

[6] M. Alekhnovich and A. Razborov. Lower bounds for the polynomial calculus: non-binomial case. *Proceedings of the Steklov Institute of Mathematics*, 242:18–35, 2003.

[7] M. Alekhnovich, J. Johannsen, T. Pitassi, and A. Urquhart. An exponential separation between regular and general resolution. *Theory of Computing*, 3:81–102, 2007.

[8] M. Alekhnovich and A. Razborov. Satisfiability, branch-width and Tseitin tautologies. *Computational Complexity*, 2011. **In this volume**.

[9] M. Alekhnovich. Linear diophantine equations over polynomials and soft decoding of Reed-Solomon codes. *IEEE Transactions on Information Theory*, 51(7):2257–2265, 2005.

[10] M. Alekhnovich and E. Ben-Sasson. Linear upper bounds for random walk on small density random 3-CNFs. *SIAM Journal on Computing*, 36(5):1248–1263, 2007.

[11] M. Alekhnovich. More on average case vs approximation complexity. *Computational Complexity*, 2011. **in this volume**.

[12] M. Alekhnovich, E. Hirsch, and D. Itsykson. Exponential lower bounds for the running time of DPLL algorithms on satisfiable formulas. *Journal of Automated Reasoning*, 35(1-3):51–72, 2005.

[13] M. Alekhnovich, M. Braverman, V. Feldman, A. R. Klivans, and T. Pitassi. The complexity of properly learning simple concept classes. *Journal of Computer and System Sciences*, 74(1):16–34, 2008.

[14] M. Alekhnovich. Lower bounds for k-DNF resolution on random 3-CNFs. *Computational Complexity*, 2011. **In this volume**.

[15] M. Alekhnovich, A. Borodin, J. Buresh-Oppenheim, R. Impgaliazzo, A. Magen, and T. Pitassi. Toward a model for backtracking and dynamic programming. *Computational Complexity*, 2011. **In this volume**.

[16] M. Alekhnovich, S. Arora, and I. Tourlakis. Toward strong nonapproximability results in the Lovász-Schrijver hierarchy. *Computational Complexuty*, 2011. **In this volume**.

[17] M. Alekhnovich, S. Khot, G. Kindler, and N. Vishnoi. Hardness of approximating the closest vector problem with pre-processing. *Computational Complexuty*, 2011. **In this volume**.