Recent Trends in Algorithms and Complexity (Mysore Park Workshop Series, August 10-12, 2012)

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Preamble The main topics we chose to cover this year included (a) algorithmic game theory, (b) optimization hierarchies, (c) polynomial identity testing, and (d) algorithmic property testing. Many of these – except possibly (c) – were not touched upon in recent workshops or conferences in India, even though very interesting work has come out and continues. The workshop was well-attended with 70 participants, among them 26 professors/researchers and 54 students. Each session had a theme covered by a tutorial or survey, followed by shorter talks on specific results in detail.

First day (morning) Optimization hierarchies are systematic ways to add local constraints to linear/semidefinite programs in order to achieve better approximations to their optimal integer or combinatorial solutions. Venkatesan Guruswami (CMU) gave a tutorial talk introducing Sherali-Adams and Lasserre hierarchies, explaining their applications in combinatorial optimization. In a subsequent talk, he showed how to round Lasserre solutions to get nearly-optimal solutions to certain NP-hard graph partitioning problems on *most* graphs. Here, *most* means the graphs whose eigenvalues decay fast. At the other extreme are graphs with slow eigenvalue decay but all known examples of these, e.g., planar graphs, bounded genus graphs, or graphs excluding fixed minors, come with rich structural properties and hence, are easy. This means that the algorithmically hard instances must be new, non-trivial families of graphs with slow eigenvalue decay.

First day (afternoon) With the advent of internet auctions, the last decade has seen an explosion of work in algorithmic game theory and economics – with the Gödel Prize 2012 going to the same area. Deeparnab Chakrabarty (MSR India) explained the basic terminology like Nash equilibrium, Arrow-Debreu exchange market, Walrasian equilibrium, Vickrey auction, VCG mechanism (welfare maximization) in his tutorial talk. Finding the sweet spot or equilibrium in the market, for several agents/players simultaneously, is a computationally hard problem. Jugal Garg and Ruta Mehta (both IIT Bombay, now Georgia Tech) gave talks on their recent positive results along these lines. Jugal's talk was on how Lemke's method for Linear Complementarity Problem (LCP) can be used to compute market equilibrium efficiently in many natural instances. Ruta talked about rank-1 bimatrix games, where the pay-off matrices for the two players add up to a rank-1 matrix. (In comparison, the pay-off matrices in zero-sum games add up to zero matrix.) Her recent work gives a polynomial time algorithm for computing Nash equilibrium of any rank-1 bimatrix game exactly, and simplifies several well-known proofs such as existence and oddness of Nash equilibria, and the index theorem of Shapley for these bimatrix games.

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Naveen Garg (IIT Delhi) gave a talk on a recent result by Polacek and Svensson on the Santa Claus problem (max-min fair allocation). It is a strange optimization problem where the optimum value can be efficiently estimated within a factor of 4 (Asadpour et al.) but no efficient algorithm was known to actually give a 4-approximate solution. Polacek and Svensson give a quasi-polynomial time algorithm to do this, and Naveen presented his simplification of their proof.

Second day (morning) We started with a tutorial by Manindra Agrawal (IIT Kanpur) on the arithmetic complexity of polynomial families. Arithmetic complexity of a polynomial is the size of its representation as an arithmetic circuit with addition and multiplication gates. Manindra explained the VP vs. VNP problem – an arithmetic analog of P vs. NP due to Valiant – which, if true, would rule out low complexity arithmetic circuits for many polynomials like the permanent, Jones polynomial, Tutte polynomial. Polynomial identity testing of small-depth arithmetic circuits provides an approach to solving VP vs. VNP problem, and recent results by Kayal-Saraf, Saxena-Seshadhri, Agrawal-Vinay, and Agrawal-Saha-Saxena-Seshadhri indicate successful inroads. Following Manindra, Chandan Saha (MPI Saarbrucken, now IISc Bangalore) talked about the recent work that uses Jacobians to capture algebraic independence, and improves upon and simplifies previous results on polynomial identity testing.

Second day (afternoon) In property testing, we want to efficiently test whether a given instance satisfies a property or is far from doing so. These tests often make only a small number of queries and cleverly exploit structural properties of instances. Sourav Chakraborty (CMI) gave a tutorial on property testing, followed by a short talk on testing boolean function isomorphism.

Economist Lloyd Shapley, who shared the Nobel Prize this year, is well-known for the Gale-Shapley algorithm to find stable matchings. A matching is stable if no pair can find better partners for both by deviating from the current pairing. However, such matchings may not be optimal for many individuals. Kavitha Telikepalli (TIFR) talked about popular matchings, a generalization of stable matching, and linear time algorithms to compute these.

Vipul Goyal (MSR India) gave a talk on his recent result about constructing non-malleable commitments using only one-way functions. Non-malleable commitments are basic building blocks in cryptographic protocols like secure auctions but all previously known constructions were either based on non-standard cryptographic assumptions or used too many rounds of communication.

Third day (morning) Graph sparsifier is a weighted subgraphs of a given graph that preserves the original eigenspectrum up to a small multiplicative error, and thereby all the cut values and many other graph properties. A graph on n vertices can have $O(n^2)$ edges and a surprising result by Batson-Spielman-Srivastava gives a deterministic algorithm to construct sparsifiers of $O(n)$ size for any graph. There are randomized variants of this algorithm with nearly-linear running time. Nikhil Srivastava (Princeton, now MSR India) gave a tutorial on various approaches that eventually lead to the Batson-Spielman-Srivastava result, and then talked about several applications of these techniques in probability, metric embedding, and numerical linear algebra.

Summary Mysore Park workshop series has enabled us to bring together all the researchers working in algorithms and complexity together, and expose graduate students from India to the current hot topics. We are glad to see larger and active student participation. Therefore, we tried to focus on recent topics that do not usually get covered in graduate courses or other conferences/workshops in India. We thank Mysore Park Workshops series for their support and for opening up Infosys Mysore campus as an ideal venue for fruitful academic interactions.