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Proceedings

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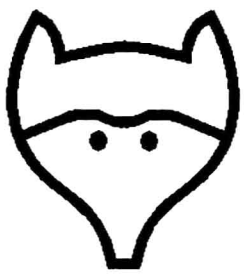

Foreword

The papers in these proceedings were presented at the 41st Annual Symposium on Foundations of Computer Science (FOCS '00), sponsored by the IEEE Computer Society Technical Committee on Mathematical Foundations of Computing. The Conference was held in Redondo Beach, CA, November 12-14, 2000.

The program committee consisted of Sanjeev Arora (Princeton), Avrim Blum (Carnegie Mellon), Faith Fich (University of Toronto), Leslie Ann Goldberg (Warwick), Michael Goodrich (Johns Hopkins), Monika Henzinger (Google), Joe Kilian (NECI), Yishay Mansour (Tel-Aviv), R. Ravi (Carnegie Mellon), Leonard Schulman (Georgia Tech & Caltech), Michael Sipser (MIT), Mario Szegedy (Institute for Advanced Studies), Umesh Vazirani (UC Berkeley), David Williamson (IBM Watson), and David Zuckerman (UT Austin & UC Berkeley).

The program committee met on June 23-24, 2000 and selected 66 papers from 206 detailed abstracts submitted. The submissions were not refereed, and many of them represent reports of continuing research. It is expected that most of these papers will appear in a more complete and polished form in scientific journals in the future. In addition to the regular program, Jeff Ullman gave his Donald E. Knuth Prize lecture at the conference.

The committee selected the paper "Stable Distributions, Pseudorandom Generators, Embeddings and Data Stream Computation" by Piotr Indyk to receive the Machtey Award for best student-authored paper. There were many excellent candidates for this award.

The committee wishes to thank all of those who submitted papers for consideration, as well as those who helped with the process of evaluating the submissions. A list of the latter individuals appears in these proceedings under the heading "Reviewers". The program committee also wishes to thank Joe Kilian for his help with the electronic submission server and Danielle Young for the production of these proceedings.

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Machtey Award

"Stable Distributions, Pseudorandom Generators, Embeddings and Data Stream Computation"

Piotr Indyk

Knuth Prize

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Entropy Waves, the Zig-Zag Graph Product, and New Constant-Degree Expanders and Extractors

EXTENDED ABSTRACT

Omer Reingold* Salil Vadhan† Avi Wigderson‡

Abstract

The main contribution of this work is a new type of graph product, which we call the **zig-zag product**. *Taking a product of a large graph with a small graph, the resulting graph inherits (roughly) its size from the large one, its degree from the small one, and its expansion properties from both! Iteration yields simple explicit constructions of constant-degree expanders of every size, starting from one constant-size expander.*

Crucial to our intuition (and simple analysis) of the properties of this graph product is the view of expanders as functions which act as "entropy wave" propagators — they transform probability distributions in which entropy is concentrated in one area to distributions where that concentration is dissipated. In these terms, the graph product affords the constructive interference of two such waves.

A variant of this product can be applied to extractors, giving the first explicit extractors whose seed length depends (poly)logarithmically on only the entropy deficiency of the source (rather than its length) and that extract almost all the entropy of high min-entropy sources. These high min-entropy extractors have several interesting applications, including the first constant-degree explicit expanders which beat the "eigenvalue bound."

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1 Introduction

1.1 Expanders

Expanders are graphs which are sparse but nevertheless highly connected. Such graphs have been used to address many fundamental problems in computer science, on topics including network design (e.g. [Pip87, PY82, AKS83]), complexity theory ([Val77, Sip88, Urq87]), derandomization ([NN93, INW94, IW97]), coding theory ([SS96, Spi96]), and cryptography ([GIL+90]). Standard probabilistic arguments ([Pin73]) show that almost every constant-degree (≥ 3) graph is an expander. However, explicitly constructing such graphs seemed to be much harder and this led to an exciting and extensive body of research, developed mainly by mathematicians intrigued by this computer science challenge.

Most of this work was guided by the sufficient[1] condition for the expansion of (infinite families of constant-degree regular) graphs discovered by Tanner [Tan84] (see also [AM85]): the second largest eigenvalue of the adjacency matrix should be strictly smaller than the degree. This naturally led researchers to consider algebraic constructions, where this eigenvalue can be estimated. The celebrated sequence of papers [Mar73, GG81, AM85, AGM87, JM87, LPS88, Mar88, Mor94] provided such constant-degree expanders. All these graphs are extremely simple to describe: given the name of a vertex (in binary), its neighbors can be computed in polynomial time (or even logarithmic space). This level of explicitness is essential for many of the applications. However, the analysis bounding the eigenvalue is quite sophisticated (and often based on deep mathematical results). Thus, it is hard to intuitively understand why these graphs are expanders.

A deviation from this path was taken by Ajtai [Ajt94], who proposed a combinatorial construction of cubic expanders. It starts with an arbitrary cubic N-vertex graph and applies a sequence of polynomially many local opera-

[1] This condition turned out to be necessary as well [Alo86].

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