

*Commenced Publication in 1973*

Founding and Former Series Editors:

Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

## Editorial Board

David Hutchison

*Lancaster University, UK*

Takeo Kanade

*Carnegie Mellon University, Pittsburgh, PA, USA*

Josef Kittler

*University of Surrey, Guildford, UK*

Jon M. Kleinberg

*Cornell University, Ithaca, NY, USA*

Alfred Kobsa

*University of California, Irvine, CA, USA*

Friedemann Mattern

*ETH Zurich, Switzerland*

John C. Mitchell

*Stanford University, CA, USA*

Moni Naor

*Weizmann Institute of Science, Rehovot, Israel*

Oscar Nierstrasz

*University of Bern, Switzerland*

C. Pandu Rangan

*Indian Institute of Technology, Madras, India*

Bernhard Steffen

*University of Dortmund, Germany*

Madhu Sudan

*Microsoft Research, Cambridge, MA, USA*

Demetri Terzopoulos

*University of California, Los Angeles, CA, USA*

Doug Tygar

*University of California, Berkeley, CA, USA*

Gerhard Weikum

*Max-Planck Institute of Computer Science, Saarbruecken, Germany*

Ashish Goel Friedrich C. Simmel  
Petr Sosík (Eds.)

# DNA Computing

14th International Meeting  
on DNA Computing, DNA14  
Prague, Czech Republic, June 2-9, 2008  
Revised Selected Papers

## Volume Editors

Ashish Goel  
Management Science and Engineering,  
and Computer Science, Terman 311  
Stanford University  
Stanford, CA, USA  
E-mail: ashishg@stanford.edu

Friedrich C. Simmel  
Physics Department  
TU Munich  
Garching, Germany  
E-mail: simmel@ph.tum.de

Petr Sosík  
Institute of Computer Science  
Faculty of Philosophy and Science  
Silesian University  
Opava, Czech Republic  
E-mail: petr.sosik@fpf.slu.cz

Library of Congress Control Number: 2009936573

CR Subject Classification (1998): F.1, I.2.9, I.2.11, F.2.2, J.3

LNCS Sublibrary: SL 1 – Theoretical Computer Science and General Issues

ISSN 0302-9743  
ISBN-10 3-642-03075-0 Springer Berlin Heidelberg New York  
ISBN-13 978-3-642-03075-8 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

springer.com

© Springer-Verlag Berlin Heidelberg 2009  
Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India  
Printed on acid-free paper SPIN: 12625284 06/3180 5 4 3 2 1 0

# Preface

The 14th international meeting on DNA computation took place in the Czech Republic in Prague, June 2–9, 2008. During the last 14 years the DNA Computing meetings have been the key forum at the boundary between computer science, biochemistry and nanotechnology where the most recent results have been presented and their authors have met. Their scientific program includes mathematical foundations and theoretical study of DNA computing – or bio-computing in general – and recent experimental results in DNA nanotechnology, nanoscience and nanocomputing. It continues to be one of the most exciting interdisciplinary meetings, as exemplified by the diverse nature of contributions in this volume.

The meeting began with tutorial talks by Friedrich Simmel (“Molecular Biology for Computer Scientists”), Nadrian Seeman (“Structural DNA Nanotechnology”), and Yasubumi Sakakibara (“Formal Grammars for DNA Computation and Bioinformatics”). During the meeting, a number of excellent keynote speakers gave an up-to-date overview of different aspects of DNA computing and biochemical information processing. Luca Cardelli talked about “Molecules as Automata,” while Niles Pierce gave an exciting talk entitled “Molecular Choreography—Programming Nucleic Acid Self-Assembly and Disassembly Pathways.” In a more biological talk, Laura Landweber discussed “RNA-Guided, Epigenetic Programming and Re-programming of Genomic Information in Ciliates,” and Ming Li gave an overview of “Modern Homology Search.”

The meeting was concluded by a Nanoday with beautiful presentations by Christof Niemeyer, Kurt Gothelf, Andrew Ellington and David Pine.

In total, the meeting was attended by 85 researchers from 14 countries from Asia, North America and Europe. The DNA14 Program Committee received a total number of 59 submissions, of which 25 were presented orally. Their topics included theoretical models of biomolecular computing, demonstrations of biomolecular computing processes, self-assembly systems, DNA nanostructures and nanomachines, biotechnological and other applications of DNA computing and other related themes. This proceedings volume contains improved versions of 15 papers selected from these oral contributions.

We wish to express our gratitude to the members of the Program Committee, the local organizers, the sponsor – Silesian University in Opava – and the Steering Committee who made DNA14 a great success.

November 2008

Ashish Goel  
Friedrich Simmel  
Petr Sosík

# Organization

## Program Committee

Ashish Goel (Co-chair)	Stanford University, USA
Friedrich Simmel (Co-chair)	Technical University Munich, Germany
Martyn Amos	Manchester Metropolitan University, UK
Alessandra Carbone	Pierre et Marie Curie, France
Ho-Lin Chen	Stanford University, USA
Mark Daley	University of Western Ontario, Canada
Russell Deaton	University of Arkansas, USA
Rudolf Freund	Technical University of Vienna, Austria
Hendrik Jan Hoogeboom	Leiden University, The Netherlands
Jozef Kelemen	Silesian University, Czech Republic
Thomas LaBean	Duke University, USA
Maurice Margenstern	University of Metz, France
Yongli Mi	Hong Kong University of Science and Technology, Hong Kong
Satoshi Murata	Tokyo Institute of Technology, Japan
Mitsunori Ogihara	University of Rochester, USA
Ion Petre	University of Turku, Finland
John A. Rose	Ritsumeikan APU, Japan
Yasubumi Sakakibara	Keio University, Japan
Lloyd Smith	University of Wisconsin-Madison, USA
David Soloveichik	California Institute of Technology, USA
Petr Sosík	Silesian University in Opava, Czech Republic
Andrew Turberfield	Oxford University, UK
Reidun Twarock	University of York, UK
Ron Weiss	Princeton University, USA
Bernard Yurke	Boise State University, USA
Byoung-Tak Zhang	Seoul National University, Korea

## Steering Committee

Lila Kari (Chair)	University of Western Ontario, Canada
Leonard Adleman	University of Southern California, USA (honorary member)
Anne Condon	University of British Columbia, Canada
Masami Hagiya	University of Tokyo, Japan
Natasha Jonoska	University of Southern Florida, USA
Chengde Mao	Purdue University, USA
Giancarlo Mauri	University of Milan-Bicocca, Italy
Satoshi Murata	Tokyo Institute of Technology, Japan

## VIII Organization

Gheorghe Paun	Romanian Academy, Bucharest and Seville University, Spain
John Reif	Duke University, USA
Grzegorz Rozenberg	University of Leiden, The Netherlands
Nadrian Seeman	New York University, USA
Andrew Tuberfield	Oxford University, UK
Erik Winfree	California Institute of Technology, USA

### **Local Organizing Committee - Prague**

Petr Sosík (chair)	Silesian University in Opava, Czech Republic
Michaela Ačová	Silesian University in Opava, Czech Republic
Ludek Cienciala	Silesian University in Opava, Czech Republic
Lucie Ciencialová	Silesian University in Opava, Czech Republic
Magdalena Chmelařová	Silesian University in Opava, Czech Republic
Alica Kelemenová	Silesian University in Opava, Czech Republic
Sarka Vavrečková	Silesian University in Opava, Czech Republic
Milena Zeithamlová	Action M Agency, Czech Republic

### **Sponsors**

Silesian University in Opava

# Table of Contents

Experimental Validation of Signal Dependent Operation in Whiplash PCR . . . . .	1
<i>Ken Komiya, Masayuki Yamamura, and John A. Rose</i>	
Towards DNA Comparator: The Machine That Compares DNA Concentrations . . . . .	11
<i>Fumiaki Tanaka, Takashi Tsuda, and Masami Hagiya</i>	
Construction of Photon-Fueled DNA Nanomachines by Tethering Azobenzenes as Engines . . . . .	21
<i>Xingguo Liang, Hidenori Nishioka, Nobutaka Takenaka, and Hiroyuki Asanuma</i>	
Operon Structure Optimization by Random Self-assembly . . . . .	33
<i>Yusuke Nakagawa, Katsuyuki Yugi, Kenji Tsuge, Mitsuhiro Itaya, Hiroshi Yanagawa, and Yasubumi Sakakibara</i>	
Isothermal Reactivating Whiplash PCR for Locally Programmable Molecular Computation . . . . .	41
<i>John H. Reif and Urmi Majumder</i>	
DNA as a Universal Substrate for Chemical Kinetics (Extended Abstract) . . . . .	57
<i>David Soloveichik, Georg Seelig, and Erik Winfree</i>	
A Simple DNA Gate Motif for Synthesizing Large-Scale Circuits (Extended Abstract) . . . . .	70
<i>Lulu Qian and Erik Winfree</i>	
Tiamat: A Three-Dimensional Editing Tool for Complex DNA Structures . . . . .	90
<i>Sean Williams, Kyle Lund, Chenxiang Lin, Peter Wonka, Stuart Lindsay, and Hao Yan</i>	
Connecting the Dots: Molecular Machinery for Distributed Robotics . . . . .	102
<i>Yuriy Brun and Dustin Reishus</i>	
Polyomino-Safe DNA Self-assembly via Block Replacement . . . . .	112
<i>Chris Luhrs</i>	
Robust Self-assembly of Graphs . . . . .	127
<i>Stanislav Angelov, Sanjeev Khanna, and Mirkó Visontai</i>	
Time Optimal Self-assembly for 2D and 3D Shapes: The Case of Squares and Cubes . . . . .	144
<i>Florent Becker, Éric Rémila, and Nicolas Schabanel</i>	

Self-assembly of Discrete Self-similar Fractals (Extended Abstract) . . . . .	156
<i>Matthew J. Patitz and Scott M. Summers</i>	
Speeding Up Local-Search Type Algorithms for Designing DNA Sequences under Thermodynamical Constraints . . . . .	168
<i>Suguru Kawashimo, Yen Kaow Ng, Hirotaka Ono, Kunihiko Sadakane, and Masafumi Yamashita</i>	
Sequentiality Induced by Spike Number in SNP Systems . . . . .	179
<i>Oscar H. Ibarra, Andrei Păun, and Alfonso Rodríguez-Patón</i>	
<b>Author Index</b> . . . . .	191