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Dedicated to Cristian S. Calude
on the Occasion of His 60th Birthday
Auckland, New Zealand, February 21-24, 2012
Revised Selected and Invited Papers

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Preface

The International Workshop on Theoretical Computer Science (WTCS 2012), dedicated to Cristian Calude's 60th birthday, took place during February 21–24 in 2012 in Auckland, New Zealand. This volume titled *Computation, Physics and Beyond*, based on WTCS 2012, is published in the LNCS Festschrifts Series by Springer. The volume contains contributions from invited speakers and regular papers that present either expository/survey results or original research in the following areas (in which Cristian Calude has either made significant contributions or has an interest):

- Algorithmic information theory
- Algorithms
- Automata and formal languages
- Computing and natural sciences
- Computability and applications
- Logic and applications
- Philosophy of computation
- Physics and computation
- Unconventional models of computation

Prof. Cristian (Cris) S. Calude

The following eminent researchers were invited to give lectures at the conference and contribute to the Festschrift volume.

D. Bridges (Canterbury University)
C. Câmpeanu (University of Prince Edward Island)
B. Cooper (Leeds University)
R. Freivalds (University of Latvia)
H. Jürgensen (University of Western Ontario)
G. Longo (École Polytechnique, Paris)
S. Marcus (Romanian Academy)
H. Maurer (Graz Technical University)
J. Patarin (Université Versailles)
B. Pavlov (Massey University)
G. Rozenberg (Leiden University)
A. Shen (University of Marseille)
L. Staiger (Martin Luther University)
K. Svozil (Vienna Technical University)
K. Tadaki (Chuo University, Tokyo)
S. Yu (University of Western Ontario)
L. Vîţă (NZ Customs)
H. Zenil (Wolfram Research)
M. Zimand (Towson Univ)
S. Wolfram (Wolfram Research)

Other invited contributors agreeing to contribute to this Festschrift volume dedicated to Cris include:

G. Chaitin (IBM Research, New York)
R. Downey (Victoria University, NZ)
M. Dumitrescu (University of Bucharest)
L. Kari (University of Western Ontario)
Y. Manin (Max Planck Institute)
Gh. Păun (Romanian Academy)
A. Salomaa (Turku University)
K. Salomaa (Kingston University)
I. Streinu (Smith College)
I. Tomescu (University of Bucharest)

The Program Committee consisted of B. Cooper, F. Costa, M. J. Dinneen, P. Hertling, B. Khoussainov (Chair), F. Kroon, Y. Matiyasevich, A. Nies, Gh. Păun, G. Rozenberg, K. Salomaa, L. Staiger, A. Shen, F. Stephan and M. Zimand. They appreciate the additional work done by the following referees for the conference volume:

Vasco Brattka	Rupert Hölzl	Ulrich Speidel
Elena Calude	Yun-Bum Kim	Mike Stay
Rodney Downey	Gaven Martin	Kohtaro Tadaki
Noam Greenberg	Erik Palmgren	Karl Svozil

The careers of the three editors of this book have been influenced by Cris' research in algorithmic randomness, as well as his tireless administrating and organizing work. Soon after his arrival in Auckland in the early 1990s, Cris, jointly with Douglas Bridges, who was then at the University of Waikato, established the Centre for Discrete Mathematics and Theoretical Computer Science (CDMTCS). This led to the formation of the first computer science theory group in New Zealand. With the creation of the CDMTCS and his research work, Cris put the Computer Science Department at the University of Auckland on the map. All three of us were recruited by the department with strong support from Cris. In the mid-1990s, Calude, jointly with Khoussainov, Hertling and Wang, wrote a few papers, including "Recursively enumerable reals and Chaitin Omega numbers," which was published in the *Proceedings of STACS 1998*, and later in the journal *Theoretical Computer Science*. These papers, along with early work by Chaitin, Kučera, Kurtz, Solovay and Terwijn, laid the foundation for the development of the modern theory of algorithmic randomness as expressed in the work of Downey, Hirschfeldt, Miller, Nies, Slaman, Stephan, and many others.

The paper by Calude, Khoussainov, Hertling and Wang for the first time studied the concept of Solovay reducibility (from a 1975 manuscript) on the real numbers and introduced computably enumerable presentations of reals. The authors established some fundamental properties of Solovay reducibility, such as the equivalence classes of computably enumerable reals form an upper semi-lattice. The (Chaitin) Ω numbers form an equivalence class which is the largest element in this semi-lattice. This paper proposed the problem of whether every random computably enumerable real is a Ω number, i.e., corresponds to the largest element in the semi-lattice. This problem attracted the attention of many experts in the theory of randomness and computability. Kučera and Slaman

answered the question positively in "Randomness and recursive enumerability" (*SIAM J. of Computing*) in 2001.

A related 2002 paper also inspired by the work of Cris and his collaborators is "Randomness, computability and density" by Downey, Hirschfeldt and Nies (*SIAM J. of Computing*), where the density of the semilattice is established. A further question was whether for every splitting of an Ω number as a sum of two computably enumerable reals, one of the two has to be an Ω number as well. They answered the question in the affirmative. (Curiously, later on it turned out that O. Demuth, a constructivist working in isolation in Prague, already had known this in 1975.)

Cris' work was essential for establishing the leading role of New Zealand in the area of algorithmic randomness, which is evidenced by the recent publication of Nies' book *Computability and Randomness* published by Oxford University Press in 2009, and Downey and (former Wellington postdoc) Hirschfeldt's book *Algorithmic Randomness and Complexity* by Springer in 2010.

An Ω number is simultaneously computably enumerable and random; its weak form of computable approximability (the first property) is limited by the last property which implies bi-immunity, i.e., every algorithm can compute at most finitely many exact bits of such a number (none in the case of a Solovay's number, a special type of Ω number). The work Michael Dinneen did with Cris and, initially, with their former PhD student C.-K. Shu, combined the theoretical analysis with an extensive computation to calculate exactly the values of finitely many initial bits of a natural Ω number (64 in the first case). This result—the first computation of "a glimpse of randomness"—was extensively cited and commented on (for example, in the *New Scientist*); its meaning is discussed in Chaitin's paper included in this volume. This work paved the way for a more practical and complexity-theoretic approach to randomness, which includes theoretical and experimental studies of quantum randomness (work jointly done with Cris, M. Dumitrescu and K. Svozil). Michael appreciates his cooperation with Cris in the emerging field of unconventional/natural computing, e.g., the bead search/sorting was developed with their former PhD student J. Arulanandham, and in the study of the complexity of mathematical problems (joint work with E. Calude). They organized many CDMTCS international conferences together, including most editions in the series of conferences "Unconventional Computation" that started in Auckland in 1998.

We all value our friendship with Cris and the mentoring advice he has provided over the past 16 years. Our close relationship with Cris goes beyond academic collaboration. For instance, Bakh wishes that he could play tennis at the level of Cris; Michael is envious of Cris' air gun collection; André wishes he could also organize a workshop on a boat going down the Nile river.

The local Organizing Committee at the University of Auckland wishes to acknowledge the contributions of Gill Dobbie and Bob Doran. We thank the Department of Computer Science (University of Auckland), the Faculty of Science (University of Auckland), and the New Zealand Marsden Fund for monetary support. Last but not least, it is a great pleasure to thank the fine co-operation

with the *Lecture Notes in Computer Science* team of Springer for producing this volume in time for the conference.

This book is organized as follows into themes related to Cris' research area. The first part consists of a couple of papers discussing Cris' life achievements. This is then followed by papers in the three general areas of complexity, computability and randomness; physics, philosophy (and logic) and computation; and algorithms, automata and formal models (including unconventional computing). Finally, we mention that the front cover art of this book highlights the first 40 exact bits of an Ω number recently computed by Cris and the first editor.

November 2011

Michael J. Dinneen
Bakhadyr Khoussainov
André Nies

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