Preface

Research in the field of VLSI design was initiated at the Computer Science and Engineering Department of the Indian Institute of Technology (IIT), Kharagpur, India, in the mid-1980s. One of the major emphases for this research group was VLSI testing, specifically the design of on-chip *Built-In-Self-Test (BIST)* structures to enhance the testability of VLSI circuits. In the very early stage of its activities, the research group made the following major observations:

(a) The VLSI design community always prefers to have simple, regular, and modular building blocks to realize a complex function.

(b) In the era of submicron technology, an interconnection on the silicon floor is likely to behave more like a device rather than as a simple signal path.

(c) *Linear Feedback Shift Register (LFSR)* is normally used as the basic BIST structure for testing digital circuits. LFSR has been widely studied in the last few decades, and excellent analytical tools based on polynomial algebra are available to characterize its behavior. However, it is not modular or cascadable, and it has an irregular and nonlocal interconnection structure.

Given this background, the research group looked for a simple, regular, modular, and cascadable structure with a local neighborhood—as an alternative to LFSR. The two-state-per-cell, three-neighborhood cellular automata (CA) is identified to be an ideal structure supporting all these requirements. On further scrutiny, it is observed that there exists no analytical tool to characterize its state-transition behavior. This has motivated us to undertake exhaustive study of CA behavior in order to formulate an elegant matrix algebraic tool that will completely characterize its behavior and develop a wide variety of applications. Six Ph.D. theses that encompassed all the related research works were completed under my supervision from 1988 to 1995.

This book provides a comprehensive report of all of these research materials, some of which have already been published as research papers in international journals and conferences.

Full-scale research thrust was initiated around 1987–88 to develop the theory and applications of CA. Dr. Aloke Kumar Das completed his Ph.D. thesis entitled "Theory and Applications of Cellular Automata for Built-In-Self-Test Structure." Matrix algebraic tools were developed to characterize group CA and develop its applications in the field of VLSI testing. CA-based schemes for generation of *pseudorandom* and *pseudoexhaustive* patterns were developed, and work on a CA-based *signature analyzer* was initiated as well. This research laid the foundation for subsequent work. Another researcher, Dr. Susanta Misra, carried forward the application of CA as BIST structure supporting both test generation and signature analyzer in his thesis "Theory and Application of Additive Cellular Automata for easily testable VLSI circuit design." Dr. Misra also initiated the research in the field of CA-based finite-state machine (FSM) synthesis, in collaboration with another research scholar, Dr. Biswadip Mitra, who did his Ph.D. thesis work in the field of "Synthesis of Testable VLSI Designs from High-Level Specifications."

The next phase of activities was initiated with the research work of Dr. Dipanwita Roy Chowdhury in her thesis entitled "Theory and Applications of Additive Cellular Automata for Reliable and Testable VLSI Circuit Design." Dr. Chowdhury concentrated on developing schemes for CA-based easily testable FSM, bit-error correcting code, byte error correcting code, and characterization of two-dimensional CA. At approximately the same time, Dr. Sukumar Nandi initiated his research work in the field of CA-based universal pattern generation, data encryption, and synthesis of easily testable combinational logic. His Ph.D. thesis, "Additive Cellular Automata: Theory and Application for Testable Circuit Design and Data Encryption," also covered new characterizations of group CA behavior and CA-based tools for fault diagnosis.

In all of the aforementioned research works, nongroup CA were not studied in detail. The exhaustive study of nongroup CA behavior was undertaken by Dr. Santanu Chattopadhyay in his Ph.D. thesis entitled "Some Studies on Theory and Applications of Additive Cellular Automata." He also extended CA applications in the fields of hashing function generation, multiple byte error correcting code, and board-level fault diagnosis.

In their M.Tech. theses (1995–1996) Subhasish Mitra and Arindam Majumdar extended the theory for characterizing $GF.2^p$/ CA and developed the $GF.2^2$/ CA-based model for amino acids. Subhasish also refined the earlier work in the field of testable synthesis. The current ongoing work deals with a CA-based model for (i) amino acid and protein chain, and (ii) fractals. Dr. Swagata Dasgupta and Dr. Dipanwita Roy Chowdhury are currently doing research in these areas at IIT-Kharagpur.

Dr. Santanu Chattopadhyay, currently a faculty member of the Department of Computer Science and Technology at Bengal Engineering College (a Deemed University), is further extending the research in the field of CA.

In 1993–94 we prepared the first version of the manuscript for this book. Since then further interesting developments have occurred in the field of CA theory and applications. All these new results will be published in Volume 2 of *Additive Cellular Automata: Theory and Applications*.

Dr. Dipanwita Roy Chowdhury, Dr. Sukumar Nandi, and Dr. Santanu Chattopadhyay, the three members of the research team, are the coauthors of this book. In addition, a large number of undergraduate and postgraduate students have contributed substantially to the research work for developing CA theory and applications. Notable among them are Saugata Basu, Supratik Chakrabarty, B. Vamsi, Manjit Ray, and Sumit Roy, who joined this research group and completed their undergraduate projects during the period 1990 to 1994. Supratik Chakrabarty completed his undergraduate project in 1993 and made excellent contributions. Professor Indranil Sengupta, a faculty member of the Computer Science and Engineering Department of IIT Kharagpur has always come forward to help us in this research work. A large number of other faculty members in the department provided inspiration and encouragement for the activities of this group as well. Notable among them are Professors A.K. Majumdar, S.C. De Sarkar, D. Sarkar, A. Basu, S. Ghosh, S.P. Pal, P.P. Chakrabarty, P.P. Das, T.K. Dey, A. Pal, and P. Bhattacharya. I convey my sincere thanks to all of the students and faculty members whose help was essential to carry forward the research work reported in this book. It is also necessary to acknowledge the financial support received from the Department of Electronics (DOE), Government of India, for the sponsored research projects. Two DOE officials, Dr. U.P. Phadke and Dr. S.P. Uttam, were extremely helpful and provided excellent support that enabled us to make such an extensive research in the theory and applications of CA in the past eight years. I would also like to express my thanks to Intel Corporation and Mr. Manpreet S. Khaira of Intel Corporation (and my ex-student from IIT Kharagpur) for inviting me as a Visiting Faculty at Intel in 1997. This has greatly facilitated the proofreading and final correction of the manuscript of this book. Finally, I would like to convey my sincere thanks and appreciation for the untiring support and encouragement that this research group received from my wife, Dr. Jayasree Pal Chaudhuri (a medical officer at IIT Kharagpur B C Roy Technology Hospital).

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