Preface

Julian Francis Miller

This book is a tribute to Julian Francis Miller's breadth of ideas and achievements in computer science, evolutionary algorithms and genetic programming, electronics, unconventional computing, artificial chemistry, and theoretical biology. Well-known for both Cartesian Genetic Programming and evolution *in materio*, Julian has further interests from quantum computing to artificial chemistries. He has over 200 refereed publications (http://www.cartesiangp.co.uk/jfm-publications.html); here, we highlight just a few of his major accomplishments.

Julian started his life in science as mathematical physicist working on the interaction of solitons in various nonlinear partial differential equations such as the sine-Gordon equation [3, 5], and the modified Korteweg-de Vries equation [4]. He entered classical computer science with his paper on synthesis and optimisation of networks implemented with universal logic modules [1, 16, 30]. Julian's interest in optimisation led him to genetic algorithms, which he employed for optimisation of field-programmable arrays [26], Reed-Muller logical functions [15], finite-state machines [2], and evolving combinatorial logic circuits [18, 22, 23] and non-uniform cellular automata [27, 28].

Julian combined his interests in physics and computer science in work on constant complexity algorithm for solving Boolean satisfiability problems on quantum computers, and quantum algorithm for finding multiple matches [31]. Julian's ideas in optimisation of circuits and quantum computing are reflected in Younes' Chapter "Using Reed-Muller Expansions in the Synthesis and Optimization of Boolean Quantum Circuits".

Julian's interest in combining natural processes and computation expanded from physics to include the exciting world of biological processes, such as evolution and morphogenesis. He used principles of morphogenesis to evolve computing circuits and programs [14, 17, 19]. These aspects of Julian's work are reflected in Chapters "Evolvable Hardware Challenges: Past, Present and the Path to a Promising Future" by Haddow and Tyrell, "Artificial Development" by Kuyucu et al., and Banzhaf's "Some Remarks on Code Evolution with Genetic Programming".

In 2000, Julian, together with Peter Thomson, presented a fully developed concept of Cartesian Genetic Programming (CGP) [24]. There, a program is genetically represented as a directed graph, including automatically defined functions [29] and self-modifying operators [10]. This approach has become very popular, because it allows the discovery of efficient solutions across a wide range of mathematical problems and algorithms. Several chapters of the book manifest the success of CGP in diverse application areas: "Designing Digital Systems Using Cartesian Genetic Programming and VHDL" by Henson et al.; "Breaking the Stereotypical Dogma of Artificial Neural Networks with Cartesian Genetic Programming" by Khan and Ahmad; "Approximate Computing: An Old Job for Cartesian Genetic Programming?" by Sekanina; "Medical Applications of Cartesian Genetic Programming" by Smith and Lones; "Multi-step Ahead Forecasting Using Cartesian Genetic Programming" by Dzalbs and Kalganova; "Cartesian Genetic Programming for Control Engineering" by Clarke; "Bridging the Gap Between Evolvable Hardware and Industry Using Cartesian Genetic Programming" by Vasicek; "Combining Local and Global Search: A Multi-objective Evolutionary Algorithm for Cartesian Genetic Programming" by Kaufmann and Platzner.

In 2001, Miller and Hartman published "Untidy evolution: Evolving messy gates for fault tolerance" [21]. Their ideas of exploiting of "messiness" to achieve "optimality"—"natural evolution is, par excellence, an algorithm that exploits the physical properties of materials"—gave birth to a new field of unconventional computing: evolution *in materio* [7, 12, 20]. The evolution *in materio* approach has proved very successful in discovering logical circuits in liquid crystals [11–13], disordered ensembles of carbon nanotubes [6, 7, 25] (and Chapter "Evolution in Nanomaterio: The NASCENCE Project" by Broersma), slime mould (Chapter "Discovering Boolean Gates in Slime Mould" by Harding et al.), living plants (Chapter "Computers from Plants We Never Made: Speculations" by Adamatzky et al.), and reaction-diffusion chemical systems ("Chemical Computing Through Simulated Evolution" by Bull et al.).

Julian's inspiration from nature has not neglected the realm of chemistry: he has exploited chemical ideas in the development of a novel form of artificial chemistry,

used to explore emergent complexity [8, 9]. Chapter "Sub-Symbolic Artificial Chemistries" by Faulkner et al. formalises this approach.

The book will be a pleasure to explore for readers from all walks of life, from undergraduate students to university professors, from mathematicians, computers scientists, and engineers to chemists and biologists.

York, UK
Bristol, UK
June 2017

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http://www.springer.com/978-3-319-67996-9

Inspired by Nature
Essays Presented to Julian F. Miller on the Occasion of his 60th Birthday
Stepney, S.; Adamatzky, A. (Eds.)
2018, X, 387 p. 168 illus., 78 illus. in color., Hardcover
ISBN: 978-3-319-67996-9