Neuromorphic Processing A New Frontier In Scaling

Resistive Random Access Memory (RRAM)Advances in Neuromorphic Hardware Exploiting Emerging Nanoscale DevicesEngineering Applications of Neural NetworksSpiking Neuron ModelsThe End of ErrorCognitive Hyperconnected Digital TransformationAnalysis of Parallel Spike TrainsQuantum ComputingFundamental NeuroscienceAtomic SwitchPhotonic Reservoir ComputingAnalog VLSIFrontiers in High Energy Density PhysicsOptics for AI and AI for Optics2003 IEEE Conference on Electron Devices and Solid-State CircuitsMemristors for Neuromorphic Circuits and Artificial Intelligence ApplicationsNeural Computation in Embodied Closed-Loop Systems for the Generation of Complex Behavior: From Biology to TechnologyOptimization for Machine LearningNeuromorphic PhotonicsNeural and Brain ModelingAnalog VLSI Implementation of Neural SystemsNeuro-inspired Information ProcessingThe Silicon EyeAdvances in Computational IntelligenceOptical Communication with Chaotic LasersDeep Learning for Radar and Communications Automatic Target RecognitionNanotechnology and Neuroscience: Nano-electronic, Photonic and Mechanical Neuronal InterfacingNeural EngineeringTinyMLFrontiers of Materials ResearchNeuromorphic Systems EngineeringComputational Systems NeurobiologyPattern Recognition and Machine LearningLearning in Energy-Efficient Neuromorphic Computing: Algorithm and Architecture Co-DesignAn Analog VLSI System for Stereoscopic VisionMemristor NetworksHeterogeneous ComputingApplications of Emerging Memory TechnologyCommunications and CodingGlial ⇔ Neuronal Signaling

Resistive Random Access Memory (RRAM)

This state-of-the-art survey offers a renewed and refreshing focus on the progress in evolutionary computation, in neural networks, and in fuzzy systems. The book presents the expertise and experiences of leading researchers spanning a diverse spectrum of computational intelligence in these areas. The result is a balanced contribution to the research area of computational intelligence that should serve the community not only as a survey and a reference, but also as an inspiration for the future advancement of the state of the art of the field. The 13 selected chapters originate from lectures and presentations given at the IEEE World Congress on Computational Intelligence, WCCI 2012, held in Brisbane, Australia, in June 2012.

Advances in Neuromorphic Hardware Exploiting Emerging Nanoscale Devices

Neural Engineering, 2nd Edition, contains reviews and discussions of contemporary and relevant topics by leading investigators in the field. It is intended to serve as a textbook at the graduate and advanced undergraduate level in a bioengineering curriculum. This principles and applications approach to neural engineering is essential reading for all

academics, biomedical engineers, neuroscientists, neurophysiologists, and industry professionals wishing to take advantage of the latest and greatest in this emerging field.

Engineering Applications of Neural Networks

The proceedings from the 2003 IEEE Conference on Electron Devices and Solid-State Circuits.

Spiking Neuron Models

This book constitutes the refereed proceedings of the 16th International Conference on Engineering Applications of Neural Networks, EANN 2015, held in Rhodes, Greece, in September 2015. The 36 revised full papers presented together with the abstracts of three invited talks and two tutorials were carefully reviewed and selected from 84 submissions. The papers are organized in topical sections on industrial-engineering applications of ANN; bioinformatics; intelligent medical modeling; life-earth sciences intelligent modeling; learning-algorithms; intelligent telecommunications modeling; fuzzy modeling; robotics and control; smart cameras; pattern recognition-facial mapping; classification; financial intelligent modeling; echo state networks.

The End of Error

Cognitive Hyperconnected Digital Transformation provides an overview of the current Internet of Things (IoT) landscape, ranging from research, innovation and development priorities to enabling technologies in a global context. It is intended as a standalone book in a series that covers the Internet of Things activities of the IERC-Internet of Things European Research Cluster, including both research and technological innovation, validation and deployment. The book builds on the ideas put forward by the European Research Cluster, the IoT European Platform Initiative (IoT-EPI) and the IoT European Large-Scale Pilots Programme, presenting global views and state-of-the-art results regarding the challenges facing IoT research, innovation, development and deployment in the next years. Hyperconnected environments integrating industrial/business/consumer IoT technologies and applications require new IoT open systems architectures integrated with network architecture (a knowledge-centric network for IoT), IoT system design and open, horizontal and interoperable platforms managing things that are digital, automated and connected and that function in real-time with remote access and control based on Internet-enabled tools. The IoT is bridging the physical world with the virtual world by combining augmented reality (AR), virtual reality (VR), machine learning and artificial intelligence (AI) to support the physical-digital integrations in the Internet of mobile things based on sensors/actuators, communication, analytics technologies, cyber-physical systems, software, cognitive systems and IoT platforms with multiple functionalities. These IoT systems have the

potential to understand, learn, predict, adapt and operate autonomously. They can change future behaviour, while the combination of extensive parallel processing power, advanced algorithms and data sets feed the cognitive algorithms that allow the IoT systems to develop new services and propose new solutions. IoT technologies are moving into the industrial space and enhancing traditional industrial platforms with solutions that break free of device-, operating system- and protocol-dependency. Secure edge computing solutions replace local networks, web services replace software, and devices with networked programmable logic controllers (NPLCs) based on Internet protocols replace devices that use proprietary protocols. Information captured by edge devices on the factory floor is secure and accessible from any location in real time, opening the communication gateway both vertically (connecting machines across the factory and enabling the instant availability of data to stakeholders within operational silos) and horizontally (with one framework for the entire supply chain, across departments, business units, global factory locations and other markets). End-to-end security and privacy solutions in IoT space require agile, context-aware and scalable components with mechanisms that are both fluid and adaptive. The convergence of IT (information technology) and OT (operational technology) makes security and privacy by default a new important element where security is addressed at the architecture level, across applications and domains, using multi-layered distributed security measures. Blockchain is transforming industry operating models by adding trust to untrusted environments, providing distributed security mechanisms and transparent access to the information in the chain. Digital technology platforms are evolving, with IoT platforms integrating complex info

Cognitive Hyperconnected Digital Transformation

Solid and transparent data analysis is the most important basis for reliable interpretation of experiments. The technique of parallel spike train recordings using multi-electrode arrangements has been available for many decades now, but only recently gained wide popularity among electro physiologists. Many traditional analysis methods are based on firing rates obtained by trial-averaging, and some of the assumptions for such procedures to work can be ignored without serious consequences. The situation is different for correlation analysis, the result of which may be considerably distorted if certain critical assumptions are violated. The focus of this book is on concepts and methods of correlation analysis (synchrony, patterns, rate covariance), combined with a solid introduction into approaches for single spike trains, which represent the basis of correlations analysis. The book also emphasizes pitfalls and potential wrong interpretations of data due to violations of critical assumptions.

Analysis of Parallel Spike Trains

This volume contains the proceedings of a workshop on Analog Integrated Neural Systems held May 8, 1989, in connection with the International Symposium on Circuits and Systems. The presentations were chosen to encompass the entire range

of topics currently under study in this exciting new discipline. Stringent acceptance requirements were placed on contributions: (1) each description was required to include detailed characterization of a working chip, and (2) each design was not to have been published previously. In several cases, the status of the project was not known until a few weeks before the meeting date. As a result, some of the most recent innovative work in the field was presented. Because this discipline is evolving rapidly, each project is very much a work in progress. Authors were asked to devote considerable attention to the shortcomings of their designs, as well as to the notable successes they achieved. In this way, other workers can now avoid stumbling into the same traps, and evolution can proceed more rapidly (and less painfully). The chapters in this volume are presented in the same order as the corresponding presentations at the workshop. The first two chapters are concerned with fmding solutions to complex optimization problems under a predefmed set of constraints. The first chapter reports what is, to the best of our knowledge, the first neural-chip design. In each case, the physics of the underlying electronic medium is used to represent a cost function in a natural way, using only nearest-neighbor connectivity.

Quantum Computing

Fundamental Neuroscience, 3rd Edition introduces graduate and upper-level undergraduate students to the full range of contemporary neuroscience. Addressing instructor and student feedback on the previous edition, all of the chapters are rewritten to make this book more concise and student-friendly than ever before. Each chapter is once again heavily illustrated and provides clinical boxes describing experiments, disorders, and methodological approaches and concepts. Capturing the promise and excitement of this fast-moving field, Fundamental Neuroscience, 3rd Edition is the text that students will be able to reference throughout their neuroscience careers! New to this edition: 30% new material including new chapters on Dendritic Development and Spine Morphogenesis, Chemical Senses, Cerebellum, Eye Movements, Circadian Timing, Sleep and Dreaming, and Consciousness Additional text boxes describing key experiments, disorders, methods, and concepts Multiple model system coverage beyond rats, mice, and monkeys Extensively expanded index for easier referencing

Fundamental Neuroscience

Recent scientific and technical advances have made it possible to create matter in the laboratory under conditions relevant to astrophysical systems such as supernovae and black holes. These advances will also benefit inertial confinement fusion research and the nation's nuclear weapon's program. The report describes the major research facilities on which such high energy density conditions can be achieved and lists a number of key scientific questions about high energy density physics that can be addressed by this research. Several recommendations are presented that would facilitate the development of a comprehensive strategy for realizing these research opportunities.

Atomic Switch

Artificial intelligence is deeply involved in our daily lives via reinforcing the digital transformation of modern economies and infrastructure. It relies on powerful computing clusters, which face bottlenecks of power consumption for both data transmission and intensive computing. Meanwhile, optics (especially optical communications, which underpin today's telecommunications) is penetrating short-reach connections down to the chip level, thus meeting with AI technology and creating numerous opportunities. This book is about the marriage of optics and AI and how each part can benefit from the other. Optics facilitates on-chip neural networks based on fast optical computing and energy-efficient interconnects and communications. On the other hand, AI enables efficient tools to address the challenges of today's optical communication networks, which behave in an increasingly complex manner. The book collects contributions from pioneering researchers from both academy and industry to discuss the challenges and solutions in each of the respective fields.

Photonic Reservoir Computing

An introduction to the design of analog VLSI circuits. Neuromorphic engineers work to improve the performance of artificial systems through the development of chips and systems that process information collectively using primarily analog circuits. This book presents the central concepts required for the creative and successful design of analog VLSI circuits. The discussion is weighted toward novel circuits that emulate natural signal processing. Unlike most circuits in commercial or industrial applications, these circuits operate mainly in the subthreshold or weak inversion region. Moreover, their functionality is not limited to linear operations, but also encompasses many interesting nonlinear operations similar to those occurring in natural systems. Topics include device physics, linear and nonlinear circuit forms, translinear circuits, photodetectors, floating-gate devices, noise analysis, and process technology.

Analog VLSI

Explains current co-design and co-optimization methodologies for building hardware neural networks and algorithms for machine learning applications This book focuses on how to build energy-efficient hardware for neural networks with learning capabilities—and provides co-design and co-optimization methodologies for building hardware neural networks that can learn. Presenting a complete picture from high-level algorithm to low-level implementation details, Learning in Energy-Efficient Neuromorphic Computing: Algorithm and Architecture Co-Design also covers many fundamentals and essentials in neural networks (e.g., deep learning), as well as hardware implementation of neural networks. The book begins with an overview of neural networks. It then discusses algorithms for utilizing and training rate-based artificial neural networks. Next comes an introduction to various options for executing neural networks, ranging from general-purpose processors to

specialized hardware, from digital accelerator to analog accelerator. A design example on building energy-efficient accelerator for adaptive dynamic programming with neural networks is also presented. An examination of fundamental concepts and popular learning algorithms for spiking neural networks follows that, along with a look at the hardware for spiking neural networks. Then comes a chapter offering readers three design examples (two of which are based on conventional CMOS, and one on emerging nanotechnology) to implement the learning algorithm found in the previous chapter. The book concludes with an outlook on the future of neural network hardware. Includes cross-layer survey of hardware accelerators for neuromorphic algorithms Covers the co-design of architecture and algorithms with emerging devices for much-improved computing efficiency Focuses on the co-design of algorithms and hardware, which is especially critical for using emerging devices, such as traditional memristors or diffusive memristors, for neuromorphic computing Learning in Energy-Efficient Neuromorphic Computing: Algorithm and Architecture Co-Design is an ideal resource for researchers, scientists, software engineers, and hardware engineers dealing with the ever-increasing requirement on power consumption and response time. It is also excellent for teaching and training undergraduate and graduate students about the latest generation neural networks with powerful learning capabilities.

Frontiers in High Energy Density Physics

Neuromorphic Systems Engineering: Neural Networks in Silicon emphasizes three important aspects of this exciting new research field. The term neuromorphic expresses relations to computational models found in biological neural systems, which are used as inspiration for building large electronic systems in silicon. By adequate engineering, these silicon systems are made useful to mankind. Neuromorphic Systems Engineering: Neural Networks in Silicon provides the reader with a snapshot of neuromorphic engineering today. It is organized into five parts viewing state-of-the-art developments within neuromorphic engineering from different perspectives. Neuromorphic Systems Engineering: Neural Networks in Silicon provides the first collection of neuromorphic systems descriptions with firm foundations in silicon. Topics presented include: large scale analog systems in silicon neuromorphic silicon auditory (ear) and vision (eye) systems in silicon learning and adaptation in silicon merging biology and technology micropower analog circuit design analog memory analog interchipcommunication on digital buses £/LIST£ Neuromorphic Systems Engineering: Neural Networks in Silicon serves as an excellent resource for scientists, researchers and engineers in this emerging field, and may also be used as a text for advanced courses on the subject.

Optics for AI and AI for Optics

Using memristors one can achieve circuit functionalities that are not possible to establish with resistors, capacitors and inductors, therefore the memristor is of great pragmatic usefulness. Potential unique applications of memristors are in

spintronic devices, ultra-dense information storage, neuromorphic circuits and programmable electronics. Memristor Networks focuses on the design, fabrication, modelling of and implementation of computation in spatially extended discrete media with many memristors. Top experts in computer science, mathematics, electronics, physics and computer engineering present foundations of the memristor theory and applications, demonstrate how to design neuromorphic network architectures based on memristor assembles, analyse varieties of the dynamic behaviour of memristive networks and show how to realise computing devices from memristors. All aspects of memristor networks are presented in detail, in a fully accessible style. An indispensable source of information and an inspiring reference text, Memristor Networks is an invaluable resource for future generations of computer scientists, mathematicians, physicists and engineers.

2003 IEEE Conference on Electron Devices and Solid-State Circuits

The Future of Numerical Computing Written by one of the foremost experts in high-performance computing and the inventor of Gustafson’s Law, The End of Error: Unum Computing explains a new approach to computer arithmetic: the universal number (unum). The unum encompasses all IEEE floating-point formats as well as fixed-point and exact integer arithmetic. This new number type obtains more accurate answers than floating-point arithmetic yet uses fewer bits in many cases, saving memory, bandwidth, energy, and power. A Complete Revamp of Computer Arithmetic from the Ground Up Richly illustrated in color, this groundbreaking book represents a fundamental change in how to perform calculations automatically. It illustrates how this novel approach can solve problems that have vexed engineers and scientists for decades, including problems that have been historically limited to serial processing. Suitable for Anyone Using Computers for Calculations The book is accessible to anyone who uses computers for technical calculations, with much of the book only requiring high school math. The author makes the mathematics interesting through numerous analogies. He clearly defines jargon and uses color-coded boxes for mathematical formulas, computer code, important descriptions, and exercises.

Memristors for Neuromorphic Circuits and Artificial Intelligence Applications

Deep learning networks are getting smaller. Much smaller. The Google Assistant team can detect words with a model just 14 kilobytes in size—small enough to run on a microcontroller. With this practical book you’ll enter the field of TinyML, where deep learning and embedded systems combine to make astounding things possible with tiny devices. Pete Warden and Daniel Situnayake explain how you can train models small enough to fit into any environment. Ideal for software and hardware developers who want to build embedded systems using machine learning, this guide walks you through creating a series of TinyML projects, step-by-step. No machine learning or microcontroller experience is necessary. Build a speech recognizer, a camera that detects people, and a magic wand that responds to gestures Work with Arduino and ultra-low-power microcontrollers Learn the essentials of ML and how to train your own models Train models to understand audio,

image, and accelerometer data Explore TensorFlow Lite for Microcontrollers, Google’s toolkit for TinyML Debug applications and provide safeguards for privacy and security Optimize latency, energy usage, and model and binary size

Neural Computation in Embodied Closed-Loop Systems for the Generation of Complex Behavior: From Biology to Technology

Written by the inventors and leading experts of this new field, the book results from the International Symposium on “Atomic Switch: Invention, Practical use and Future Prospects” which took place in Tsukuba, Japan on March 27th - 28th, 2017. The book chapters cover the different trends from the science and technology of atomic switches to their applications like brain-type information processing, artificial intelligence (AI) and completely novel functional electronic nanodevices. The current practical uses of the atomic switch are also described. As compared with the conventional semiconductor transistor switch, the atomic switch is more compact (~1/10) with much lower power consumption (~1/10) and scarcely influenced by strong electromagnetic noise and radiation including cosmic rays in space (~1/100). As such, this book is of interest to researchers, scholars and students willing to explore new materials, to refine the nanofabrication methods and to explore new and efficient device architectures.

Optimization for Machine Learning

This authoritative resource presents a comprehensive illustration of modern Artificial Intelligence / Machine Learning (AI/ML) technology for radio frequency (RF) data exploitation. It identifies technical challenges, benefits, and directions of deep learning (DL) based object classification using radar data, including synthetic aperture radar (SAR) and high range resolution (HRR) radar. The performance of AI/ML algorithms is provided from an overview of machine learning (ML) theory that includes history, background primer, and examples. Radar data issues of collection, application, and examples for SAR/HRR data and communication signals analysis are discussed. In addition, this book presents practical considerations of deploying such techniques, including performance evaluation, energy-efficient computing, and the future unresolved issues.

Neuromorphic Photonics

This book sets out to build bridges between the domains of photonic device physics and neural networks, providing a comprehensive overview of the emerging field of "neuromorphic photonics." It includes a thorough discussion of evolution of neuromorphic photonics from the advent of fiber-optic neurons to today’s state-of-the-art integrated laser neurons, which are a current focus of international research. Neuromorphic Photonics explores candidate interconnection architectures and devices for integrated neuromorphic networks, along with key functionality such as learning. It is written at a level

accessible to graduate students, while also intending to serve as a comprehensive reference for experts in the field.

Neural and Brain Modeling

This is the first textbook on pattern recognition to present the Bayesian viewpoint. The book presents approximate inference algorithms that permit fast approximate answers in situations where exact answers are not feasible. It uses graphical models to describe probability distributions when no other books apply graphical models to machine learning. No previous knowledge of pattern recognition or machine learning concepts is assumed. Familiarity with multivariate calculus and basic linear algebra is required, and some experience in the use of probabilities would be helpful though not essential as the book includes a self-contained introduction to basic probability theory.

Analog VLSI Implementation of Neural Systems

If you look around you will find that all computer systems, from your portable devices to the strongest supercomputers, are heterogeneous in nature. The most obvious heterogeneity is the existence of computing nodes of different capabilities (e.g. multicore, GPUs, FPGAs,). But there are also other heterogeneity factors that exist in computing systems, like the memory system components, interconnection, etc. The main reason for these different types of heterogeneity is to have good performance with power efficiency. Heterogeneous computing results in both challenges and opportunities. This book discusses both. It shows that we need to deal with these challenges at all levels of the computing stack: from algorithms all the way to process technology. We discuss the topic of heterogeneous computing from different angles: hardware challenges, current hardware state-of-the-art, software issues, how to make the best use of the current heterogeneous systems, and what lies ahead. The aim of this book is to introduce the big picture of heterogeneous computing. Whether you are a hardware designer or a software developer, you need to know how the pieces of the puzzle fit together. The main goal is to bring researchers and engineers to the forefront of the research frontier in the new era that started a few years ago and is expected to continue for decades. We believe that academics, researchers, practitioners, and students will benefit from this book and will be prepared to tackle the big wave of heterogeneous computing that is here to stay.

Neuro-inspired Information Processing

This is an introduction to spiking neurons for advanced undergraduate or graduate students. It can be used with courses in computational neuroscience, theoretical biology, neural modeling, biophysics, or neural networks. It focuses on phenomenological approaches rather than detailed models in order to provide the reader with a conceptual framework. No prior knowledge beyond undergraduate mathematics is necessary to follow the book. Thus it should appeal to students or

researchers in physics, mathematics, or computer science interested in biology; moreover it will also be useful for biologists working in mathematical modeling.

The Silicon Eye

This book describes the use of modern micro- and nanofabrication technologies to develop improved tools for stimulating and recording electrical activity in neuronal networks. It provides an overview of the different ways in which the “nano-world” can be beneficial for neuroscientists, including improvement of mechanical adhesion of cells on electrodes, tight-sealed extracellular recordings or intracellular approaches with strongly reduced invasiveness and tools for localized electrical or optical stimulation in optogenetics experiments. Specific discussion of fabrication strategies is included, to provide a comprehensive guide to develop micro and nanostructured tools for biological applications. A perspective on integrating these devices with state-of-the-art technologies for large-scale in vitro and in vivo experiments completes the picture of neuronal interfacing with micro- and nanostructures.

Advances in Computational Intelligence

Glial Neuronal Signaling fills a need for a monograph/textbook to be used in advanced courses or graduate seminars aimed at exploring glial-neuronal interactions. Even experts in the field will find useful the authoritative summaries of evidence on ion channels and transporters in glia, genes involved in signaling during development, metabolic cross talk and cooperation between astrocytes and neurons, to mention but a few of the timely summaries of a wide range of glial-neuronal interactions. The chapters are written by the top researchers in the field of glial-neuronal signaling, and cover the most current advances in this field. The book will also be of value to the workers in the field of cell biology in general. When we think about the brain we usually think about neurons. Although there are 100 billion neurons in mammalian brain, these cells do not constitute a majority. Quite the contrary, glial cells and other non-neuronal cells are 10-50 times more numerous than neurons. This book is meant to integrate the emerging body of information that has been accumulating, revealing the interactive nature of the brain's two major neural cell types, neurons and glia, in brain function.

Optical Communication with Chaotic Lasers

This book covers all major aspects of cutting-edge research in the field of neuromorphic hardware engineering involving emerging nanoscale devices. Special emphasis is given to leading works in hybrid low-power CMOS-Nanodevice design. The book offers readers a bidirectional (top-down and bottom-up) perspective on designing efficient bio-inspired hardware. At the nanodevice level, it focuses on various flavors of emerging resistive memory (RRAM) technology. At the algorithm level,

it addresses optimized implementations of supervised and stochastic learning paradigms such as: spike-time-dependent plasticity (STDP), long-term potentiation (LTP), long-term depression (LTD), extreme learning machines (ELM) and early adoptions of restricted Boltzmann machines (RBM) to name a few. The contributions discuss system-level power/energy/parasitic trade-offs, and complex real-world applications. The book is suited for both advanced researchers and students interested in the field.

Deep Learning for Radar and Communications Automatic Target Recognition

RRAM technology has made significant progress in the past decade as a competitive candidate for the next generation non-volatile memory (NVM). This lecture is a comprehensive tutorial of metal oxide-based RRAM technology from device fabrication to array architecture design. State-of-the-art RRAM device performances, characterization, and modeling techniques are summarized, and the design considerations of the RRAM integration to large-scale array with peripheral circuits are discussed. Chapter 2 introduces the RRAM device fabrication techniques and methods to eliminate the forming process, and will show its scalability down to sub-10 nm regime. Then the device performances such as programming speed, variability control, and multi-level operation are presented, and finally the reliability issues such as cycling endurance and data retention are discussed. Chapter 3 discusses the RRAM physical mechanism, and the materials characterization techniques to observe the conductive filaments and the electrical characterization techniques to study the electronic conduction processes. It also presents the numerical device modeling techniques for simulating the evolution of the conductive filaments as well as the compact device modeling techniques for circuit-level design. Chapter 4 discusses the two common RRAM array architectures for large-scale integration: one-transistor-one-resistor (1T1R) and cross-point architecture with selector. The write/read schemes are presented and the peripheral circuitry design considerations are discussed. Finally, a 3D integration approach is introduced for building ultra-high density RRAM array. Chapter 5 is a brief summary and will give an outlook for RRAM’s potential novel applications beyond the NVM applications.

Nanotechnology and Neuroscience: Nano-electronic, Photonic and Mechanical Neuronal Interfacing

With the end of Moore's law and the emergence of new application needs such as those of the Internet of Things (IoT) or artificial intelligence (AI), neuro-inspired, or neuromorphic, information processing is attracting more and more attention from the scientific community. Its principle is to emulate in a simplified way the formidable machine to process information which is the brain, with neurons and artificial synapses organized in network. These networks can be software – and therefore implemented in the form of a computer program – but also hardware and produced by nanoelectronic circuits. The 'material' path allows very low energy consumption, and the possibility of faithfully reproducing the shape and

dynamics of the action potentials of living neurons (biomimetic approach) or even being up to a thousand times faster (high frequency approach). This path is promising and welcomed by the major manufacturers of nanoelectronics, as circuits can now today integrate several million neurons and artificial synapses.

Neural Engineering

How can neural and morphological computations be effectively combined and realized in embodied closed-loop systems (e.g., robots) such that they can become more like living creatures in their level of performance? Understanding this will lead to new technologies and a variety of applications. To tackle this research question, here, we bring together experts from different fields (including Biology, Computational Neuroscience, Robotics, and Artificial Intelligence) to share their recent findings and ideas and to update our research community. This eBook collects 17 cutting edge research articles, covering neural and morphological computations as well as the transfer of results to real world applications, like prosthesis and orthosis control and neuromorphic hardware implementation.

TinyML

Starting with an introduction to the fundamental physics in chaotic instabilities in laser systems, this comprehensive and unified reference goes on to present the techniques and technology of synchronization of chaos in coupled lasers, as well as the many applications to lasers and optics, communications, security and information technology. Throughout, it presents the current state of knowledge, including encoding/decoding techniques, performance of chaotic communication systems, random number generation, and novel communication technologies.

Frontiers of Materials Research

Quantum mechanics, the subfield of physics that describes the behavior of very small (quantum) particles, provides the basis for a new paradigm of computing. First proposed in the 1980s as a way to improve computational modeling of quantum systems, the field of quantum computing has recently garnered significant attention due to progress in building small-scale devices. However, significant technical advances will be required before a large-scale, practical quantum computer can be achieved. Quantum Computing: Progress and Prospects provides an introduction to the field, including the unique characteristics and constraints of the technology, and assesses the feasibility and implications of creating a functional quantum computer capable of addressing real-world problems. This report considers hardware and software requirements, quantum algorithms, drivers of advances in quantum computing and quantum devices, benchmarks associated with relevant use cases, the time and resources required, and how to assess the probability of success.

Neuromorphic Systems Engineering

Photonics has long been considered an attractive substrate for next generation implementations of machine-learning concepts. Reservoir Computing tremendously facilitated the realization of recurrent neural networks in analogue hardware. This concept exploits the properties of complex nonlinear dynamical systems, giving rise to photonic reservoirs implemented by semiconductor lasers, telecommunication modulators and integrated photonic chips.

Computational Systems Neurobiology

Computational neurosciences and systems biology are among the main domains of life science research where mathematical modeling made a difference. This book introduces the many different types of computational studies one can develop to study neuronal systems. It is aimed at undergraduate students starting their research in computational neurobiology or more senior researchers who would like, or need, to move towards computational approaches. Based on their specific project, the readers would then move to one of the more specialized excellent textbooks available in the field. The first part of the book deals with molecular systems biology. Functional genomics is introduced through examples of transcriptomics and proteomics studies of neurobiological interest. Quantitative modelling of biochemical systems is presented in homogeneous compartments and using spatial descriptions. A second part deals with the various approaches to model single neuron physiology, and naturally moves to neuronal networks. A division is focused on the development of neurons and neuronal systems and the book closes on a series of methodological chapters. From the molecules to the organ, thinking at the level of systems is transforming biology and its impact on society. This book will help the reader to hop on the train directly in the tank engine.

Pattern Recognition and Machine Learning

Modern materials science builds on knowledge from physics, chemistry, biology, mathematics, computer and data science, and engineering sciences to enable us to understand, control, and expand the material world. Although it is anchored in inquiry-based fundamental science, materials research is strongly focused on discovering and producing reliable and economically viable materials, from super alloys to polymer composites, that are used in a vast array of products essential to today's societies and economies. Frontiers of Materials Research: A Decadal Survey is aimed at documenting the status and promising future directions of materials research in the United States in the context of similar efforts worldwide. This third decadal survey in materials research reviews the progress and achievements in materials research and changes in the materials research landscape over the last decade; research opportunities for investment for the period 2020-2030; impacts that materials research has had and is expected to have on emerging technologies, national needs, and science; and

challenges the enterprise may face over the next decade.

Learning in Energy-Efficient Neuromorphic Computing: Algorithm and Architecture Co-Design

Artificial Intelligence (AI) has found many applications in the past decade due to the ever increasing computing power. Artificial Neural Networks are inspired in the brain structure and consist in the interconnection of artificial neurons through artificial synapses. Training these systems requires huge amounts of data and, after the network is trained, it can recognize unforeseen data and provide useful information. The so-called Spiking Neural Networks behave similarly to how the brain functions and are very energy efficient. Up to this moment, both spiking and conventional neural networks have been implemented in software programs running on conventional computing units. However, this approach requires high computing power, a large physical space and is energy inefficient. Thus, there is an increasing interest in developing AI tools directly implemented in hardware. The first hardware demonstrations have been based on CMOS circuits for neurons and specific communication protocols for synapses. However, to further increase training speed and energy efficiency while decreasing system size, the combination of CMOS neurons with memristor synapses is being explored. The memristor is a resistor with memory which behaves similarly to biological synapses. This book explores the state-of-the-art of neuromorphic circuits implementing neural networks with memristors for AI applications.

An Analog VLSI System for Stereoscopic Vision

Memristor Networks

Documents the ongoing efforts of the billion-dollar technology company, Foveon, to develop sophisticated digital capabilities for artificially intelligent machines that will far outstrip the abilities of today's computers, in an account that profiles the company's key contributors while citing their role in transforming startups into Fortune 500 businesses. 30,000 first printing.

Heterogeneous Computing

An Analog VLSI System for Stereoscopic Vision investigates the interaction of the physical medium and the computation in both biological and analog VLSI systems by synthesizing a functional neuromorphic system in silicon. In both the synthesis and analysis of the system, a point of view from within the system is adopted rather than that of an omniscient designer drawing a blueprint. This perspective projects the design and the designer into a living landscape. The motivation for a

machine-centered perspective is explained in the first chapter. The second chapter describes the evolution of the silicon retina. The retina accurately encodes visual information over orders of magnitude of ambient illumination, using mismatched components that are calibrated as part of the encoding process. The visual abstraction created by the retina is suitable for transmission through a limited bandwidth channel. The third chapter introduces a general method for interchip communication, the address-event representation, which is used for transmission of retinal data. The address-event representation takes advantage of the speed of CMOS relative to biological neurons to preserve the information of biological action potentials using digital circuitry in place of axons. The fourth chapter describes a collective circuit that computes stereodisparity. In this circuit, the processing that corrects for imperfections in the hardware compensates for inherent ambiguity in the environment. The fifth chapter demonstrates a primitive working stereovision system. An Analog VLSI System for Stereoscopic Vision contributes to both computer engineering and neuroscience at a concrete level. Through the construction of a working analog of biological vision subsystems, new circuits for building brain-style analog computers have been developed. Specific neuropysiological and psychophysical results in terms of underlying electronic mechanisms are explained. These examples demonstrate the utility of using biological principles for building brain-style computers and the significance of building brain-style computers for understanding the nervous system.

Applications of Emerging Memory Technology

The book intends to bring under one roof research work of leading groups from across the globe working on advanced applications of emerging memory technology nanodevices. The applications dealt in the text will be beyond conventional storage application of semiconductor memory devices. The text will deal with material and device physical principles that give rise to interesting characteristics and phenomena in the emerging memory device that can be exploited for a wide variety of applications. Applications covered will include system-centric cases such as – caches, NVSRAM, NVTCAM, Hybrid CMOS-RRAM circuits for: Machine Learning, In-Memory Computing, Hardware Security - RNG/PUF, Biosensing and other misc beyond storage applications. The book is envisioned for multi-purpose use as a textbook in advanced UG/PG courses and a research text for scientists working in the domain.

Communications and Coding

An up-to-date account of the interplay between optimization and machine learning, accessible to students and researchers in both communities. The interplay between optimization and machine learning is one of the most important developments in modern computational science. Optimization formulations and methods are proving to be vital in designing algorithms to extract essential knowledge from huge volumes of data. Machine learning, however, is not simply a consumer of optimization technology but a rapidly evolving field that is itself generating new optimization ideas. This book captures the

state of the art of the interaction between optimization and machine learning in a way that is accessible to researchers in both fields. Optimization approaches have enjoyed prominence in machine learning because of their wide applicability and attractive theoretical properties. The increasing complexity, size, and variety of today's machine learning models call for the reassessment of existing assumptions. This book starts the process of reassessment. It describes the resurgence in novel contexts of established frameworks such as first-order methods, stochastic approximations, convex relaxations, interior-point methods, and proximal methods. It also devotes attention to newer themes such as regularized optimization, robust optimization, gradient and subgradient methods, splitting techniques, and second-order methods. Many of these techniques draw inspiration from other fields, including operations research, theoretical computer science, and subfields of optimization. The book will enrich the ongoing cross-fertilization between the machine learning community and these other fields, and within the broader optimization community.

Glial ⇔ Neuronal Signaling

Neural and Brain Modeling reviews models used to study neural interactions. The book also discusses 54 computer programs that simulate the dynamics of neurons and neuronal networks to illustrate between unit and systemic levels of nervous system functions. The models of neural and brain operations are composed of three sections: models of generic mechanisms; models of specific neuronal systems; and models of generic operations, networks, and systems. The text discusses the computational problems related to galvanizing a neuronal population though an activity in the multifiber input system. The investigator can use a computer technique to simulate multiple interacting neuronal populations. For example, he can investigate the case of a single local region that contains two populations of neurons: namely, a parent population of excitatory cells, and a second set of inhibitory neurons. Computer simulation models predict the various dynamic activity occurring in the complicated structure and physiology of neuronal systems. Computer models can be used in "top-down" brain/mind research where the systemic, global, and emergent properties of nervous systems are generated. The book is recommended for behavioral scientists, psychiatrists, psychologists, computer programmers, students, and professors in human behavior.