REVIEW ARTICLE

Optical neural networks: progress and challenges

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Abstract

Artificial intelligence has prevailed in all trades and professions due to the assistance of big data resources, advanced algorithms, and high-performance electronic hardware. However, conventional computing hardware is inefficient at implementing complex tasks, in large part because the memory and processor in its computing architecture are separated, performing insufficiently in computing speed and energy consumption. In recent years, optical neural networks (ONNs) have made a range of research progress in optical computing due to advantages such as sub-nanosecond latency, low heat dissipation, and high parallelism. ONNs are in prospect to provide support regarding computing speed and energy consumption for the further development of artificial intelligence with a novel computing paradigm. Herein, we first introduce the design method and principle of ONNs based on various optical elements. Then, we successively review the non-integrated ONNs consisting of volume optical components and the integrated ONNs composed of on-chip components. Finally, we summarize and discuss the computational density, nonlinearity, scalability, and practical applications of ONNs, and comment on the challenges and perspectives of the ONNs in the future development trends.

Introduction

Artificial intelligence (AI) has penetrated diverse fields in society and obtained achievements beyond humanity. Neural networks play a crucial role as the core technology supporting the development of AI. In the 1940s, McCulloch and Pitts introduced the working principle of neural networks and the structure of neurons[1,2]. In 1949, Hebb systematically elucidated the theory of neuropsychology[3]. During the 1950s, critical issues regarding the development of AI were discussed and raised[4], which promoted the crucial technologies in neural networks and the establishment of the discipline of AI. In 1958, Rosenblatt systematically introduced the mathematical model and working principle of perceptron[5], laying a significant foundation for the further development of neural networks. In 1986, following early pioneering work, Rumelhart, Hinton, and Williams proposed the error back-propagation algorithm to train multi-layer perceptrons[6].

In 1990, LeCun et al. introduced a convolutional neural network based on the back-propagation algorithm and demonstrated its application performance in handwritten digit recognition[7]. In 2012, Krizhevsky et al. proposed deep convolutional neural networks[8], which further improved the inference abilities of neural networks and made the application fields of AI more extensive[9–11].

In the meantime, the rapid development of semiconductor process technology has created a host of advanced electronic computing hardware[18–22] with better performance than CPUs in the past decade. The advanced computing hardware predominantly ensures the computing efficiency requirements of neural networks during the iteration process, thereby promoting the rapid development and application of AI in multitudinous fields. However, the machining accuracy of semiconductor manufacturing technology has approached 3nm[23], and the size has drawn near the physical limit of the transistor. Transistors with such sizes are highly susceptible to quantum tunneling and thermal effects, making them difficult to work well. Accordingly, improving the machining accuracy of semiconductor processes to acquire higher computing power will be unsustainable. The development of neural network technology relies on

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Progress In Neural Networks

Derong Liu,Zeng-Guang Hou

Progress In Neural Networks:

    Progress in Neural Networks ,1995   **Progress in Neural Networks, Volume Five** Charles L. Wilson,1997 This volume has a special thematic focus on the architecture of neural networks It is part of a series that reviews research in natural and synthetic neural networks as well as research in modelling analysis design and development of neural networks in software and hardware areas Contributions from researchers and practitioners serve as a platform for discussion of topics of interest to the neural network and cognitive information processing communities   *Radial Basis Function Neural Networks With Sequential Learning, Progress In Neural Processing* Ying Wei Lu,P Saratchandran,Narasimman Sundararajan,1999-10-04 This book presents in detail the newly developed sequential learning algorithm for radial basis function neural networks which realizes a minimal network This algorithm created by the authors is referred to as Minimal Resource Allocation Networks MRAN The book describes the application of MRAN in different areas including pattern recognition time series prediction system identification control communication and signal processing Benchmark problems from these areas have been studied and MRAN is compared with other algorithms In order to make the book self contained a review of the existing theory of RBF networks and applications is given at the beginning   *Advances in Neural Networks - ISNN 2007* Derong Liu,Zeng-Guang Hou,2007-05-24 Annotation The three volume set LNCS 4491 4492 4493 constitutes the refereed proceedings of the 4th International Symposium on Neural Networks ISNN 2007 held in Nanjing China in June 2007 The 262 revised long papers and 192 revised short papers presented were carefully reviewed and selected from a total of 1 975 submissions The papers are organized in topical sections on neural fuzzy control neural networks for control applications adaptive dynamic programming and reinforcement learning neural networks for nonlinear systems modeling robotics stability analysis of neural networks learning and approximation data mining and feature extraction chaos and synchronization neural fuzzy systems training and learning algorithms for neural networks neural network structures neural networks for pattern recognition SOMs ICA PCA biomedical applications feedforward neural networks recurrent neural networks neural networks for optimization support vector machines fault diagnosis detection communications and signal processing image video processing and applications of neural networks   **Progress in Neural Networks** Omid M. Omidvar,1994 This series reviews research in natural and synthetic neural networks as well as reviews research in modelling analysis design and development of neural networks in software and hardware areas Contributions from researchers and practitioners aim to shape academic and professional programs in this area and serve as a platform for detailed and expanded discussion of topics of interest to the neural network and cognitive information processing communities This series should be of interest to those professionally involved in neural networks research such as lecturers and primary investigators in neural computing modelling learning memory and neurocomputers   *Progress in Neural Networks, Volume Four* Omid M. Omidvar,Rakesh Mohan,1997 This is a study of the use of neural networks for machine vision It is part of a series which

reviews research in natural and synthetic neural networks as well as in modelling analysis design and development of neural networks in software and hardware areas Contributions from researchers and practitioners serve as a platform for discussion of topics of interest to the neural network and cognitive information processing communities **Progress in Neural Information Processing** Shunichi Amari,1996 These two volumes are the papers presented at the International Conference on Neural Information Processing ICONIP 96 held in Hong Kong 24 27 September 1996 Over three hundred selected papers make up two volumes of 700 pages each Featured topics of Volume 1 are Learning Theories and Algorithms Speech and Signal Processing Pattern Recognition and Image Processing Recurrent Networks Automata and Dynamics Volume 2 focusses on Financial Engineering and Time Series Forecasting Evolutionary Computing Neurosciences and Biophysics Neural Control and Robotics Hardware Implementations Hybrid Systems and Applications plus a number of Special Sessions Other topics covered include image processing computer vision fuzzy logic pattern recognition algorithms and architectures and financial engineering These two volumes combine to cover the major topics in neural information processing and reflect the latest progress with a good balance between scientific studies and industrial applications a well as featuring neural information processing approaches on financial engineering **Progress in neural networks** Omid Omidvar,1991

Advances in Neural Networks Isnn 2009 Wen Yu,Haibo He,2009-05-07 The three volume set LNCS 5551 5552 5553 constitutes the refereed proceedings of the 6th International Symposium on Neural Networks ISNN 2009 held in Wuhan China in May 2009 The 409 revised papers presented were carefully reviewed and selected from a total of 1 235 submissions The papers are organized in 20 topical sections on theoretical analysis stability time delay neural networks machine learning neural modeling decision making systems fuzzy systems and fuzzy neural networks support vector machines and kernel methods genetic algorithms clustering and classification pattern recognition intelligent control optimization robotics image processing signal processing biomedical applications fault diagnosis telecommunication sensor network and transportation systems as well as applications **Cisterns** Alireza Dehghani-sanij,Ali Sayigh,2022-09-01 Cisterns Sustainable Development Architecture and Energy was written on beliefs that based on historical evidence and actual findings Iran is most probably the country where cisterns or Aub anbars in Farsi were first developed and built Therefore it is quite natural for the author to name cisterns in the text Aub anbars as it has been called for centuries in this country the translation of the same name having been used in other countries too Although in some books journals and papers published out of Iran by foreign and Iranian scholars the names Cistern or Water Reservoir have been used The word Aub anbar is a compound noun in Farsi Aub means water and Anbar means tank reservoir Putting them together gives the noun Aub anbarand it should be used as one word People of the region wanting reserved cool water whether in cities or in different locations across the harsh desert during their travel Queen Zubeida the wife of Khalifa Haroon Al Rasheed in 750 AD built one of these cistern closer to the town of Hiyal in Saudi Arabia so that the Pilgrims Caravans going to Mecca will have cool fresh water This book consists of

11 chapters with full analysis illustrations and photographs It makes interesting readings to those interested into vernacular architecture traditional buildings and creative thinking   *Developments in Neural Networks and Evolutionary Computing for Civil and Structural Engineering* B. H. V. Topping,1995 Includes a selection of papers presented at the Fourth International Conference on the Application of Artificial Intelligence to Civil and Structural Engineering held at Cambridge England 28 30 August 1995   Recent Advances in Artificial Neural Networks L. C. Jain,2018-05-04 Neural networks represent a new generation of information processing paradigms designed to mimic in a very limited sense the human brain They can learn recall and generalize from training data and with their potential applications limited only by the imaginations of scientists and engineers they are commanding tremendous popularity and research interest Over the last four decades researchers have reported a number of neural network paradigms however the newest of these have not appeared in book form until now Recent Advances in Artificial Neural Networks collects the latest neural network paradigms and reports on their promising new applications World renowned experts discuss the use of neural networks in pattern recognition color induction classification cluster detection and more Application engineers scientists and research students from all disciplines with an interest in considering neural networks for solving real world problems will find this collection useful   **Recent Advances in Control Problems of Dynamical Systems and Networks** Ju H. Park,2020-08-11 This edited book introduces readers to new analytical techniques and controller design schemes used to solve the emerging hottest problems in dynamic control systems and networks In recent years the study of dynamic systems and networks has faced major changes and challenges with the rapid advancement of IT technology accompanied by the 4th Industrial Revolution Many new factors that now have to be considered and which haven t been addressed from control engineering perspectives to date are naturally emerging as the systems become more complex and networked The general scope of this book includes the modeling of the system itself and uncertainty elements examining stability under various criteria and controller design techniques to achieve specific control objectives in various dynamic systems and networks In terms of traditional stability matters this includes the following special issues finite time stability and stabilization consensus synchronization fault tolerant control event triggered control and sampled data control for classical linear nonlinear systems interconnected systems fractional order systems switched systems neural networks and complex networks In terms of introducing graduate students and professional researchers studying control engineering and applied mathematics to the latest research trends in the areas mentioned above this book offers an excellent guide   Therapeutic Progress in Oncology Jacques Barbet,Adrien Foucquier,Yves Thomas,2020-04-28 The combined effects of population growth and aging have led to an increase in the number of cancers Preventing diagnosing treating and curing cancer are therefore more than ever imperatives facing medicine especially to continue the decrease in cancers mortality rates and to improve the quality of survival Over time the classic modes of treatment surgery external beam radiotherapy chemotherapy have become more refined and efficient From the beginning of

this century new therapeutic options have been developed targeted cancer therapy targeted radionuclide therapy and immunologic therapies based on monoclonal antibodies cellular therapy and vaccinations Artificial intelligence and machine learning are also being introduced to the field of oncology Starting with the basic scientific principles relevant to oncology this book explains and makes these concepts and innovations accessible to a wide audience especially in the interest of patients It also contributes to the oncological field of 4P medicine with 4P standing for predictive preventive personalized and participative   **Advances in Computers** ,1993-09-14 Advances in Computers   *Advances in the Evolutionary Synthesis of Intelligent Agents* Mukesh Patel,2001 This book explores a central issue in artificial intelligence cognitive science and artificial life how to design information structures and processes that create and adapt intelligent agents through evolution and learning Among the first uses of the computer was the development of programs to model perception reasoning learning and evolution Further developments resulted in computers and programs that exhibit aspects of intelligent behavior The field of artificial intelligence is based on the premise that thought processes can be computationally modeled Computational molecular biology brought a similar approach to the study of living systems In both cases hypotheses concerning the structure function and evolution of cognitive systems natural as well as synthetic take the form of computer programs that store organize manipulate and use information Systems whose information processing structures are fully programmed are difficult to design for all but the simplest applications Real world environments call for systems that are able to modify their behavior by changing their information processing structures Cognitive and information structures and processes embodied in living systems display many effective designs for biological intelligent agents They are also a source of ideas for designing artificial intelligent agents This book explores a central issue in artificial intelligence cognitive science and artificial life how to design information structures and processes that create and adapt intelligent agents through evolution and learning The book is organized around four topics the power of evolution to determine effective solutions to complex tasks mechanisms to make evolutionary design scalable the use of evolutionary search in conjunction with local learning algorithms and the extension of evolutionary search in novel directions   Advances in Intelligent Systems Francesco Carlo Morabito,1997 Intelligent Systems can be defined as systems whose design mainly based on computational techniques is supported in some parts by operations and processing skills inspired by human reasoning and behaviour Intelligent Systems must typically operate in a scenario in which non linearities are the rule and not as a disturbing effect to be corrected Finally Intelligent Systems also have to incorporate advanced sensory technology in order to simplify man machine interactions Several algorithms are currently the ordinary tools of Intelligent Systems This book contains a selection of contributions regarding Intelligent Systems by experts in diverse fields Topics discussed in the book are Applications of Intelligent Systems in Modelling and Prediction of Environmental Changes Cellular Neural Networks for NonLinear Filtering NNs for Signal Processing Image Processing Transportation Intelligent Systems Intelligent Techniques in Power Electronics

Applications in Medicine and Surgery Hardware Implementation and Learning of NNs   *Progress in supervised neural networks* Don R. Hush,Bill G. Horne,1993   **Insights in Technical Advances in Plant Science: 2023** Roger Deal,2025-05-13 We are now entering the third decade of the 21st Century and especially in the last years the achievements made by scientists have been exceptional leading to major advancements in the fast growing field of plant science Frontiers has organized a series of Research Topics to highlight the latest advancements in research across the field of plant science with articles from the Associate Members of our accomplished Editorial Boards This editorial initiative of particular relevance led by Dr Roger Deal Specialty Chief Editor of the Technical Advances in Plant Science section is focused on new insights novel developments current challenges latest discoveries recent advances and future perspectives in the field of Technical Advances in Plant Science The Research Topic solicits brief forward looking contributions from the editorial board members that describe the state of the art outlining recent developments and major accomplishments that have been achieved and that need to occur to move the field forward Authors are encouraged to identify the greatest challenges in the sub disciplines and how to address those challenges The goal of this special edition Research Topic is to shed light on the progress made in the past decade in the Technical Advances in Plant Science field and on its future challenges to provide a thorough overview of the field This article collection will inspire inform and provide direction and guidance to researchers in the field We welcome original research reviews perspective and thought provoking opinion articles to this Research Topic

Intelligent Information Processing with Matlab Xiu Zhang,Xin Zhang,Wei Wang,2023-10-15 This book is a comprehensive collection of technologies and methods on intelligent information processing which includes artificial neural network fuzzy logic and evolutionary computing It also introduces the latest research directions and progress in intelligent information processing such as transfer learning through convolutional neural network time series prediction clustering based on fuzzy neural network test and evaluation of the traveling salesman problem test and evaluation of continuous optimization problem and more This book promotes the development and application of intelligent information processing technology in the field of computational intelligence effectively improving the intersection and integration of intelligent information processing methods Researchers in computational intelligence and artificial intelligence technology as well as teachers students and others interested in the subject will benefit from this book

The book delves into Progress In Neural Networks. Progress In Neural Networks is a vital topic that must be grasped by everyone, from students and scholars to the general public. This book will furnish comprehensive and in-depth insights into Progress In Neural Networks, encompassing both the fundamentals and more intricate discussions.

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   - Chapter 2: Essential Elements of Progress In Neural Networks
   - Chapter 3: Progress In Neural Networks in Everyday Life
   - Chapter 4: Progress In Neural Networks in Specific Contexts
   - Chapter 5: Conclusion

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