Book Reviews

Complex-Valued Neural Networks: Theories and Applications—A. Hirose, Ed. (NJ.: World Scientific Publishing Co. Pte. Ltd., 2004, ISBN 0-981-238-561-4). *Reviewed by I. Aizenberg*

The reviewed book is devoted to the neural networks that are based on the neurons with the complex-valued weights and complex-valued activation functions. In recent years, these neural networks have become more and more popular. A number of the original solutions in pattern recognition and classification, in artificial neural information processing, in image processing and in the theory of artificial neurons and neural networks that are based on the use of complex-valued neurons have been proposed. It is very important that the use of complex-valued weights and complex-valued activation functions is not a simply theoretical generalization of the real-valued case, but it makes possible to extend the functionality both of a single neuron and a network, to obtain much more stable learning algorithms and finally to solve many complicated applied problems that either cannot be solved using the real-valued neural networks or to solve them in a simpler way and more efficiently.

The reviewed book presents the latest results in the theory of complex-valued neural networks and their applications obtained by a wide group of the authors representing a number of leading research centers. In Foreword, G. M. Georgiou, and in Chapter 1, the book editor A. Hirose provide a reader with a brief description and a brief observation of the latest trends the field.

A significant part of the book (3 chapters from 15) is devoted to the development and different applications of the pioneering idea of Naum Aizenberg. This idea is based on the deep generalization of the principles of the Boolean threshold logic to the multiple-valued case (see [1]–[3]). A key point in this approach is that the neuron's k-valued inputs and output are coded by the complex numbers that are the kth roots of unity lying on the unit circle. The activation function of a neuron that was initially proposed in [1] is in this case a function of the argument of the weighted sum: The complex plain is separated onto k equal sectors, and if the weighted sum belongs to the jth sector, the neuron's output is equal to ε^j, where $\varepsilon = \exp(\mathrm{i}2\pi/\mathrm{k})$ is a primitive kth root of unity. This neuron was later called a multivalued neuron (MVN) [3].

In Chapter 3, D.L. Lee considers an associative memory model based on MVN. A neural network that is proposed to be used as an associative memory is able to store and recall gray-scale images. The stability properties of this network under different updating modes are studied by using the energy function approach. It is proved that the model is globally convergent to a fixed point when operating in a asynchronous mode and to a cycle of length at most 2 when operating in a synchronous mode.

A different model of the MVN-based associative memory for storage and recalling of the gray-scale image is considered by H. Aoki in Chapter 9. The Fourier phase spectrum coefficients are used as the network inputs. This is very natural for any MVN-based neural network, because since the MVN states are lying on the unit circle, they are determined definitely by the phases of the corresponding complex numbers. It is also shown, how the MVN-based neural network can be used for the frequency domain image filtering.

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One more original model of the MVN-based associative memory is presented by T. Miyajima and K. Yamanaka in Chapter 12. They propose an associative memory that has a zero resting attractor for application to the multiuser detection in code-division multiple-classes communications by realizing active and inactive modes.

Other chapters present different other approaches and achievements in the field. T. Nitta in Chapter 2 considers the characteristics of decision boundaries for a single neuron and for the networked and layered neurons with a complex-valued sigmoid activation function. In Chapter 4, Y Kuroe presents an original associative memory, from which it is possible to regard a set of degenerate vectors as a pattern embedded in the memory. In Chapter 5, J. Pearson considers the Clifford networks as a further extension of the complex-valued networks and a so-called Clifford-based backpropagation learning rule. I. Nemoto considers, in Chapter 6, an associative memory based on a complex-valued Nagumo–Sato neuron and investigates its chaotic behavior. Chapter 7, written by D.P. Mandic, S.L. Goh, and A. Hanna, is dedicated to a class of data-reusing learning algorithms for complex-valued adaptive filters and applies the developed approach to signal prediction. P. Rajagopal and S. Kak proposed in Chapter 8 an algorithm, which allows a time-efficient and resource saving learning in combination with the quaternary encoding technique. In Chapter 10, M. Kinouchi and M. Hagiwara present a complex-valued recurrent neural network, which is used a time-sequential data identifier and apply it as a melody retrieval system. Chapter 11, written by Y. Zhang, describes an application of Hebbian learning rule in complex domain to direction-of-arrival problem of sensor arrays. In Chapter 13, A. Bayu and A. Hirose present a lattice complex-valued neural network for automatic generation of digital elevation map by reducing the number of phase singular points in interferometric synthetic aperture radar images. M. Takeda and T. Kishigami in Chapter 14 consider a self-oscillating phase conjugate resonator and its analogy with the Hopfield neural network. In Chapter 15, S. Kawata and A. Hirose consider a very interesting optical implementation of a neural network. They propose a coherent lightwave neural network system, whose learning and processing behavior is controllable by using its optical carrier frequency as a modulation key. Each chapter is followed by the list of references that can help a reader to extend a view on the extensively developing field. The book can be very useful for all researches, who are working in the field of neural networks, and for those researches who apply neural networks in image processing, pattern recognition, and classification. The book can also be recommended to the graduate and Ph.D. students, who specialize in artificial neural networks and to the electrical and optical engineers developing the practical applications of neural networks.

References

[1] N. N. Aizenberg, Yu. L. Ivaskiv, and D. A. Pospelov, "About one generalization of the threshold function" (in Russian), *Doklady Akademii Nauk SSSR*, vol. 196, no. 6, pp. 1287–1290, 1971.

[2] N. N. Aizenberg, Yu. L. Ivaskiv, D. A. Pospelov, and G. F. Hudiakov, "Multiple-valued threshold functions. Synthesis of the multi-valued threshold element," *Kibernetika*, vol. 1, pp. 86–94, 1973.

[3] N. N. Aizenberg and I. N. Aizenberg, "CNN based on multi-valued neuron as a model of associative memory for gray-scale images," in *Proc. IEEE 2nd Int. Workshop Cellular Neural Networks and Their Applications*, Munich, Germany, Oct. 14–16, 1992, pp. 36–41.