Foreword

Over the recent years, neural networks in the complex domain have become a very active research field. The first important time in the history of complex-valued neural networks, however, dates back to the early 1990s. That is, to a time that has been characterized by others as the aftermath of the neural network revolution. The two volumes on Parallel Distributed Processing by Rumelhart and McClelland published in 1986 turned neural computation from a niche paradigm into a dominant one for artificial intelligence. The famous chapter on back-propagation paved the way for an uncountable number of applications.

With the success of real-valued neural networks an extension to complex-valued neural networks was on the agenda of that time soon. It turned out that finding suitable activation (or output) functions for complex-valued neurons was more difficult than in the real-valued case. Moreover, the most prominent real-valued feed-forward architectures - multi-layer perceptrons and radial basis function networks - were known to be universal approximators. Meanwhile, complex-valued neural networks have long caught up with the real-valued architectures. What hindered complex-valued networks to break through in the mid 1990s was to great extent the perception of ordinary real-valued networks among researchers. They just seemed to be always good enough.

In many fields, however, real-valued methods are not adequate and complex numbers are more than just handy. We use them naturally to describe waves and related phenomena in physics. We linear combine a signal with its Hilbert transform in order to get the analytic signal. The analytic signal, which consequently lives in the complex domain, is a quite universal tool providing the local amplitude and the local phase for a signal. We make extensive use of the Fourier transform to get a global signal representation in the frequency domain. This established utilization of complex numbers always worked as an impulse to study complex-valued networks. And, it shows how broad and rich the fields of application are for these networks. In this book the reader will find successful applications in image analysis, signal processing, pattern recognition and network communications. All these chapters demonstrate complex-valued neural networks at work. They show unique features of complex-valued architectures and how they lead to effective solutions for real-world problems.

The theory of computation by complex-valued neural networks applies not only to the above-mentioned fields. It is also applicable to the fast growing and important field of quantum computing. This is due to the complex representation of quantum states and operators. The stochastic quantum world, on the other hand, brings us directly to one of the theoretical frontiers of complex-valued neural networks. Consequently, architectures like the Boltzmann machine are covered in the theoretical part of this book. As can be seen from this part, the theory of complex-valued neural computation has developed well and it covers now many architectures and concepts like recurrent networks and associative memory. With its theoretical chapters the book provides a detailed overview on recent research directions on theoretical aspects.

Complex-valued neural networks are the prototype of networks that extend real-valued architectures. Abstractly, their atoms are ordered pairs of real numbers with particular defined operations on them. In that sense, they are the minimal model of multi-dimensional neural computation. The next natural extension of this line is neural networks based on quaternions. Knowledge and understanding of the complex case is crucial for all these further networks.

The thematic and qualitative collection of papers in this book is a sign of excellent editorship. Tohru Nitta is a pioneer of neural networks in the complex domain and he remained faithful to this topic over all the years. This book shows impressive applications of complex-valued neural networks. With the careful chosen emphasis on how to utilize high-dimensional parameters the book shows unique features of complex-valued neural computation in a very original and promising way.

This book really adds momentum to the field.

Sven Buchholz *received his diploma degree in computer science and his PhD degree (summa cum laude) in computer science, both from Christian-Albrechts-Universität Kiel, Germany. His PhD thesis entitled "A Theory of Neural Computation with Clifford Algebras" was awarded as best thesis in the faculty of the academic year 2004/2005. He has authored several publications on the topic of Clifford neural networks. At the moment he is a senior researcher at the Cognitive Systems Group in Kiel. His research interest includes mathematics of neural networks, machine learning, and multidimensional signal theory. Additionally to his academic experience, he also has several years of industrial experience as a statistical consultant.*