Preface to the Third Edition

This third edition has included two major components over the second edition. The first is that a selection of new applications has been addressed. There has been a recent surge in publications using the PCNN or ICM and a few of these have been included.

The second major change has been the inclusion of Python scripts. Over the past decade Python has emerged as a very powerful tool and its use is seen in many applications in the sciences. With the inclusion of a numeric library, Python has the ability to easily handle linear algebra operations with relatively few lines of code. With such efficiency it becomes possible to embed Python scripts in the text along with the theory and applications.

Every attempt has been made to ensure that the Python scripts are complete for applications that are demonstrated here. The scripts were written with Python 2.7 since it is still the standard in LINUX distributions. Users of Python 3.x will find minor differences which are customary when translating from 2.7.

Some readers who are experienced Python programmers will notice that the codes included here could be compressed to even fewer lines. However, the intent of including code is more educational in nature and so the scripts are designed to be readable before being highly compressed.

A website hosted at http://www.binf.gmu.edu/kinser/ will maintains a ZIP file with all of the Python scripts written by the authors. The Python system, the numeric Python (NumPy), scientific Python packages (SciPy), and the Python Image Library (PIL) can be obtained from their home sites as explained in Chap. 3. All of the scripts provided by the author are copyrighted and can be used only for academic purposes. Commercial applications without expressed written permission of the script's author is prohibited.

Stockholm and Manassas, 2012

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Preface to the Second Edition

It was stated in the preface of the first edition of this book that image processing by electronic means has been a very active field for decades. This is certainly still true and the goal has been, and still is, to have a machine perform the same functions which humans do quite easily. In reaching this goal we have learned much about human mechanisms and how to apply this knowledge to image processing problems. Although there is still a long way to go, we have learned a lot during the last five or six years. This information and some ideas based upon it has been added to the second edition of this book.

The present edition includes the theory and application of two cortical models: the PCNN (the pulse coupled neural network) and the ICM (intersecting cortical model). These models are based upon biological models of the visual cortex and it is prudent to review the algorithms that strongly influenced the development of the PCNN and the ICM. The outline of the book is otherwise very much the same as in the first edition, although several new applications have been added.

In Chap. 7 a few of these applications will be reviewed including original ideas by co-workers and colleagues. Special thanks are due to Soonil D. D. V. Rughooputh, the dean of the Faculty of Science at the University of Mauritius and Harry C. S. Rughooputh, the dean of the Faculty of Engineering at the University of Mauritius.

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Preface to the First Edition

Image processing by electronic means has been a very active field for decades. The goal has been, and still is, to have a machine perform the same image functions which humans do quite easily. This goal is still far from being reached. So we must learn more about the human mechanisms and how to apply this knowledge to image processing problems. Traditionally, the activities in the brain are assumed to take place through the aggregate action of billions of simple processing elements referred to as neurons and connected by complex systems of synapses. Within the concepts of artificial neural networks, the neurons are generally simple devices performing summing, thresholding, etc. However, we show now that the biological neurons are fairly complex and perform much more sophisticated calculations than their artificial counterparts. The neurons are also very specialized and it is thought that there are several hundred types in the brain and messages travel from one neuron to another as pulses.

Recently, scientists have begun to understand the visual cortex of small mammals. This understanding has led to the creation of new algorithms that are achieving new levels of sophistication in electronic image processing. With the advent of such biologically inspired approaches, in particular with respect to neural networks, we have taken another step towards the aforementioned goal.

In our presentation of the visual cortical models we will use the term Pulse-Coupled Neural Network (PCNN). The PCNN is a neural network algorithm that produces a series of binary pulse images when stimulated with a gray scale or color image. This network is different from what we generally mean by artificial neural networks in the sense that it does not train. The goal for image processing is to eventually reach a decision on the content of that image. These decisions are generally far easier to accomplish by examining the pulse outputs of the PCNN rather than the original image. Thus, the PCNN becomes a very useful pre-processing tool. There exists, however, an argument that the PCNN is more than a pre-processor. It is possible that the PCNN also has self-organizing abilities which make it possible to use the PCNN as an associative memory. This is unusual for an algorithm that does not train.

Finally, it should be noted that the PCNN is quite feasible to implement in specialized hardware. Traditional neural networks have had a large fan-in and fan-out. In other words, each neuron was connected to several other neurons. In electronics a different "wire" is needed to make each connection and large networks are quite difficult to build. The PCNN, on the other hand, has only local connections and in most cases these are always positive. This is quite plausible for electronic implementation.

The PCNN is quite powerful and we are just beginning to explore the possibilities. This text will review the theory and then explore its known image processing applications: segmentation, edge extraction, texture extraction, object identification, object isolation, motion processing, foveation, noise suppression, and image fusion. This text will also introduce arguments as to its ability to process logical arguments and its use as a synergetic computer. Hardware realization of the PCNN will also be presented.

This text is intended for the individual who is familiar with image processing terms and has a basic understanding of previous image processing techniques. It does not require the reader to have an extensive background in these areas. Furthermore, the PCNN is not extremely complicated mathematically so it does not require extensive mathematical skills. However, this text will use Fourier image processing techniques and a working understanding of this field will be helpful in some areas.

The PCNN is fundamentally unique from many of the standard techniques being used today. Many of these fields have the same basic mathematical foundation and the PCNN deviates from this path. It is an exciting field that shows tremendous promise.

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