Preface

This book results from many years of research and teaching in a cognitive approach to vision modeling. It relates the point of view of an engineer, specialist of signal and image processing, who is willing to discover and understand the basic principles of the Human visual system, with the aim to design high-level image processing systems. In fact it is fundamentally multidisciplinary and it continuously refers to a “triangle” constituted of three main disciplines:

Neurobiology, Mathematics, Psychophysics.

At first sight, the first discipline — Neurobiology — is the very source of data about the structures and functions of the visual system’s neural circuitry. Due to the fantastic advances in neurobiology during the past decades, it is now possible to have a rather precise idea of the substratum of many visual processes. But sometimes, data is missing or incomplete (experimentation at the cell or membrane level is very difficult) so that it becomes difficult to understand the mechanism underlying some functions.

At this stage, the second discipline — Mathematics — appears as considerably helpful, especially through the theory of signals and its applications to signal and image processing. The mathematics are used to modelize the neural circuits and to formalize them into their “system” aspect. The role of formalization is to represent systems by means of sets of equations that help to categorize them easily. In another way, mathematics are particularly useful to formalize hypotheses in order to explain some given behavior or to predict other ones not yet observed. It is important to consider that mathematics are two-fold: (1) equations that constitute a code of representation and (2) manipulation of equations, which is relevant to a specialist. The neophyte or non-mathematician should not be disheartened by the apparent complexity of the mathematical formulae in this book: he (or she) has just to learn and remember the names and shapes of some equations and does not need to be able to make by him- or herself the calculations that are exposed. The text will explain which important facts and consequences are to be remembered.

Often, there are not enough biological data to explain a given property or a given behavior. Without any structural basis, mathematics cannot be of any use (no equation can be designed). The help will come then from the third discipline — Psychophysics — where experimentations can be conducted on animals or humans. Due to the recent and continuous progresses in experimental and cognitive psychology, very accurate results can be obtained in order to ascertain various hypotheses. Input-output relationships can thus be established, and system theory can be used together with signal theory to modelize the functional aspects of the sub-system under consideration.

Under such a scheme, the cooperation between *biology*, *psychology* and *signal processing* appears to be of capital interest for cognitive research. Nowadays many researchers in the world, issued from one discipline, have made the effort to come to a second one, and sometimes to the third one. This gives rise to very efficient research teams with wide-minded members able to produce a number of consistent works and significant breakthroughs.

In addition, due to the cross-fertilization between disciplines resulting from this approach, each specialist will greatly increase his or her knowledge in his or her domain, and reciprocally will be able to cast a new light on the other domains.

This book is intended for students who are newcomers in the domain of vision, as well as to confirmed researchers who are willing to discover or rediscover the various aspects of vision from the point of view of modeling. Together, neurobiologists, psychophysicists, mathematicians and researchers in signal and image processing may find in the presented approach a series of ideas and hints to help them to go further in their own specialty.

Regarding the way of reading this book, there are several possibilities. Some may take it as a popularization work on visual processes, and skim through the book in order to just catch a bird's eyeview on visual structures and their principal functions. Others may be in search for a more in-depth analysis of the visual functions through their mathematical models. They will explore all formulae and equations in order to understand the mechanisms of the visual system and then gather hints for further developments.

This book begins with a chapter devoted to the physics of light and its alterations when traversing media and optics. It will give a global idea of the complexity of the tasks which are required to the visual system before extracting useful information.

The second chapter consists in an engineer's view over the architecture of the visual system. It prepares the reader to the style of approach developed in the sequel.

The model of the retinais exposed in the third chapter, which summarizes all the basics of the retinal circuitry and the fundamental role of the retina as an image pre-processor.

In the fourth chapter, the reader will discover the concept of "neuromorphic circuits" and its application to motion estimation. Though not proven to exist in the visual system, this function is of interest for image sequences analysis.

The object of chapter five is the processing of color in the retina. It illustrates the power of biological systems to code information in a highly economical and efficient form.

Chapter six presents all the advantages of irregular sampling and of non-linear processing in the retina, making it an optimal adaptive system to extract information from the visual scene.

In chapter seven, it will be found a model of the primary visual area V1 with the fantastic role of complex cells for scene analysis, leading to algorithms for categorization, monocular perspective estimation and attentional processes. As in the retina, adaptation processes are shown and may provide an explanation to well known visual after-effects. A model of the McCollough effect illustrates these principles.

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