Book Review

Computational Colour Science using MATLAB® (Second Edition), by Stephen Westland, Caterina Ripamonti and Vien Cheung (Chichester: John Wiley & Sons Ltd., 2012) 240pp. ISBN 978-0-470-66569-5.

If you are used to, or even contemplating using MATLAB® then this book on computational colour science would be a very useful addition to your bookshelf. It provides an overview of the principles of colour science but, much more importantly, it describes the components of a MATLAB® Toolbox that comprises a number of routines that will aid data analysis, device characterisation and several other useful procedures.

It could be argued that another book on colour science is not required. Perhaps there are already too many books that start by describing the structure and working of the human eye and lead on to the principles of colour matching that form the foundations of the CIE System of Colorimetry. From there it is a short step to uniform colour spaces, colour-difference formula, chromatic adaption transforms and colour appearance models. Add in some tables of data and, given a spectral power distribution, the reader is all set to calculate those elusive tristimulus values and chromaticity coordinates. The following overview of this book will show the value of its addition to your bookshelf.

Chapter 1 of the book answers the question "Why base this book on MATLAB®?" There are perhaps at least three answers. First, MATLAB® is easily applied to arrays of data, as found in many colour science applications. Second, the programme itself contains a vast library of subprograms (M-files) that can be applied to these data, thus relieving the users of the task of writing their own, together with the associated problem of verifying that they work correctly. The addition of one or more of the many additional Toolboxes provides even more functions for specific applications, for example, image processing or statistics. Third, and perhaps most important, is the capability of MATLAB® to display graphics using simple programming statements. The rest of the Chapter, all seven pages of it, is given over to a review of the basic principles of the CIE System of Colorimetry. This might seem too brief but it is adequately referenced and provides a useful summary.

Chapter 2 provides a summary of the constructs of linear algebra. Only seven pages again but useful if your most recent exposure to the subject was at school or university!

Chapter 3 is an equally short introduction to MATLAB®: eight pages, an easy read and well worth the time to digest some of the features of this programme. Of special mention must be the backslash operator which has the ability to solve a linear system of equations, essentially to invert a non-square matrix. While the user will probably require access to the programmes' excellent help files in addition to the information in this chapter, it is well worth the time to read it.

Chapter 4 starts the first application, the calculation of tristimulus values. Yes, you can do this with a spreadsheet but if you require further calculations using these values then the use of the MATLAB® routines is much more efficient. Also in this chapter, mention is made of data interpolation and the correction of measured spectral data for instrument band-pass, subjects that are often glossed over in more scientific textbooks. The chapter ends with the plotting of a chromaticity diagram complete with full colour insert.

Chapter 5 deals with CIELAB and colour difference, again leading to a coloured two-dimensional plot. Several colour-difference formulae are considered: CIELAB, CMC (l:c), CIE 94 and CIE DE2000.

As a further enhancement, test data and answers are provided to prove to the user that the routines are working correctly.

Chapter 6 moves on to subjects that have been denoted as belonging to advanced colorimetry: chromatic adaptation and colour appearance. A brief history of chromatic adaptation transforms is presented, a subject where the CIE now only makes an indirect recommendation, leading to the CMCCAT97 transform and its method of implementation incorporating a factor to indicate the degree of adaptation. The more recent CMCCAT2000 is then introduced together with appropriate test data. Colour appearance models really demand a book of their own but the authors have provided a good, though brief, overview of the latest CIE recommendation, CIECAM02, together with an appropriate subprogram.

Chapter 7 (together with Chapter 8, this is a new chapter from the 1st Edition of this book) describes the new physiological colour spaces based, not on colour matching functions, but on cone fundamentals. While still in the realm of the vision scientist, it may be that some day soon these alternative functions will find a place in industrial colorimetry. The history presented is brief but adequate as is the description of the relevant calculations. The associated chromaticity diagram for these spaces is not yet decided but one contender, the MacLeod-Boynton Chromaticity Diagram is presented together with its method of calculation. The more complex, but not so widely known DKL Colour Space, based on post-receptoral responses, is also described.

Chapter 8 leads into one of the more applied aspects of colour science, that of the management of colour in imaging systems. Again, a brief summary of the requirements is presented, including coverage of subjects like display gamut and device calibration and characterisation via the ICC (International Color Consortium) process of colour management.

Chapter 9 presents subprograms for the characterisation of computer display devices. The case study presented applies the GOG (Gain-Offset-Gamma) model to a CRT display and some discussion is presented on the application of the principles of the model to more modern LCD displays.

Chapter 10 provides a procedure to characterise a digital camera such that it can be used to measure CIE tristimulus values. This is not a defined science but requires the use of a polynomial matrix to relate the RGB values of a camera image of a colour chart to the known XYZ tristimulus values of the coloured samples that comprise the chart. The unknown is usually the spectral responsivity of the three colour channels of the camera and, while these can be measured, it is not an easy measurement to make without specialist equipment: hence the need for a relatively simple procedure. Additional measurements must be made to allow for the non-linearity of the camera response and also the spatial non-uniformity of the image area and these are both discussed.

Chapter 11 deals with the characterisation of printers; again there is usually a very non-linear relationship between the printer inputs and the XYZ tristimulus values of the printed output image. Kubelka-Munk theory can be used to derive a relationship between input ink amounts and output colorimetry but this represents a very idealised situation that does not often occur in reality, hence the resort to modelling. While this chapter presents only an introduction to the subject, it does enable the potential user to get started on the characterisation process and, if the details do not explicitly match the user's situation, adjustments can be made to obtain a reasonable result.

The final Chapter 12 deals with multispectral imaging. In this chapter the term is used in a specific, defined manner: 'to define techniques and methods that may be used to recover spectral information from camera systems with a small number of channels – typically 3 to 8.' The authors distinguish the term multispectral imaging defined in this way, from hyperspectral imaging whereby an image is generated in a spectral sense using a larger number of channels, typically a minimum of 16. The generation of a number of basis functions that can be combined in various amounts to reconstitute a set of spectral data requires one of a number of mathematical techniques including single value decomposition (SVD), principal component analysis (PCA) and characteristic vector analysis (CVA). These methods are discussed and suitable sub-programs described together with examples that enable the recovery of spectral data from limited channel input. In many respects this chapter, of 18 pages, is the best in the book because, while there are many papers that present much more complex mathematics, this chapter describes actual numerical solutions.

The book is completed with a short Appendix that comprises a table of white point data for a number of illuminants and the two CIE Standard Observers, and then a longer Appendix that reviews the contents of the MATLAB® Colour Toolbox. This contains all of the code presented in the book and it can be downloaded from the MATLAB® Central FileExchange and is free to use. Access is also possible to a blog where bug fixes (there is one!) and comments are posted. The final pages of the book are devoted to a very thorough index.

So is this book useful? Yes, it is. Most of the chapters provide a brief but good overview to a number of specific aspects of colour science, both pure and applied, and then describe in more detail the application of a number MATLAB® sub-programs, often with worked examples or test data.

Is the book useful if you are not a MATLAB® user? Yes it is. But you will have the added task of writing your own routines to mimic those in the Colour Toolbox. You will however gain insight into how you can actually, for example, characterise a device, or derive a set of spectral basis functions.

This is the second edition of this book and it is included in the Wiley-IS&T Series on Imaging Science and Technology. The first edition was published in 2004 and there have been a number of advances in colour science, especially in its applications, that were not included in the first edition. Finally the routines have been optimised to obtain an improved balance between performance and clarity.

If you are interested in computational colour science and especially its application to imaging systems then you should have this book: it will be on your desk not on your bookshelf!

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