Stochastic Image Processing

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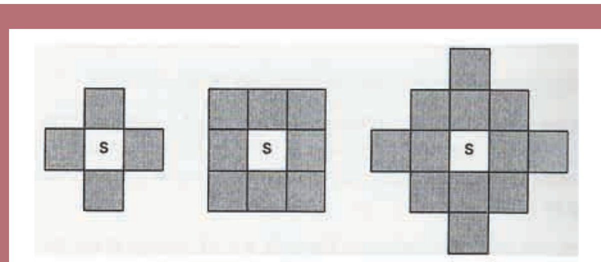
Stochastic image processing is a rapidly advancing field of signal processing that many technological devices, users and beneficiaries have come to be heavily dependant on. A particularly good example of this is the sophisticated image processing devices that have become vital tools in disease and illness identification for health practitioners. Although medical image processing and its applications are extremely valuable, many other multimedia image processing applications are just as widespread. Specific image processing techniques generally include image restoration, segmentation and feature extraction.

Some of the common problems surrounding stochastic image processing revolve around the development of a sound model that will accurately describe the image while allowing for easy data manipulation with minimal computational complexity. Once such a model is established, other mathematical methods and techniques are needed to correctly estimate each class label with minimal classification error.

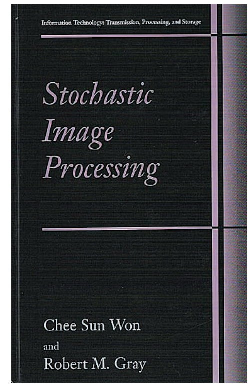
The mathematical models that are discussed in this book focus on Markov Random Fields and its many variations. Chapter 1 describes the model identification and class labelling issues in detail and also gives a general overview of the optimal solution, which is thoroughly described in the rest of the chapters. Also included in chapter 1 is a complete description of the variable notation used throughout the text as well as some common examples of stochastic image processing.

Chapter 2 discusses noncausal Markov Random Fields. The authors define several important parameters, models and mathematical definitions such as neighbourhoods, cliques, clique potentials, Markov Random Fields (MRF) and Gibbs Random Fields (GRF), to name a few. The GRF-MRF equivalence is shown by the Hammersly-Clifford theorem. Optimal class labelling schemes are investigated for both supervised and unsupervised problems and solutions to the maximum a posteriori (MAP) estimation are shown for both cases. Due to the computational demand of finding the MAP estimate by conventional means, simulated annealing (SA) procedures are explored as an alternative. The end of the chapter shows parameter estimation and a method to determine the appropriate number of class labels for unsupervised noncausal MRF images.

Chapter 3 extends the principals and techniques of 1D Markov Chains (MC) to 2D image data by methods that order the image's pixels in a causal manner. However, as a result of the ambiguous definition of image causality, several causal models can arise. A few of the causal models that are considered in this chapter are: Pseudo Hidden Markov Models (PHMM), Markov Mesh Random Fields (MMRF) and multidimensional Markov Chains (MDMC). For each situation, to find the optimal class labelling scheme, the MAP estimation is solved using recursive algorithms, namely the Viterbi algorithm. For parameter estimation, the Baum-Welch algorithm, which is a specific implementation of the expectation and maximization (EM) algorithm, is demonstrated for each causal model discussed. The chapter finishes off with a brief description of 3-D Causal Markov Models.



Examples of hierarchical neighbourhoods used for pixel-wise noncausal Markov Random Fields (MRF)



Unlike all of the other data models previously examined, multiscale Markov models can deal with image texture very well. This subject is treated in Chapter 4 where Multiscale Markov models are used to describe the interscale and intrascale statistical dependencies and relationships. Furthermore, by finding and using an appropriate Multiscale model, the development of an optimization strategy for class labelling is feasible. The appropriate treatment for textured images is shown to be a pyramid structure which would require a specific multiscale representation depending on the application. The multiscale representations discussed are the Renormalization Group (RG) approach, which uses a course to fine scale MAP optimization approach via the RG algorithm, multiscale transforms such as block-to-point mapping and wavelet coefficient modelling and interscale models which result in methods that model the scale dependencies as a time ordered Markov Chain. In order to manipulate such a representation, the principles of hidden Markov trees (HMT) are applied. In this chapter, HMT are shown to aid in parameter estimation via the EM and upward-downward algorithms. HMT are also demonstrated to simplify the process of obtaining the optimal solution to the MAP estimate. The end of the chapter introduces the optimal class labelling scheme for multiscale Markov models by using the sequential MAP estimate (SMAP).

Using a multiscale representation for an image allows for image texture to be accounted for via large scale feature extraction. However, although this may be beneficial, the computational demand for parameter estimation is discouraging. Block-wise image modelling poses a positive alternative and is discussed in Chapter 5. The discussion first begins with block-wise noncausal MRF models and then block-wise neighbourhood systems are defined. The global optimal solution for the MAP estimate is demonstrated to be similar to that of pixel-wise noncausal MRF, however is less computationally complex. Secondly, block-wise causal MRF are presented and the principles and techniques from Chapter 3 are extended from pixel-wise to block-wise causal MRF. Just as before, the MAP estimate is obtained via the Viterbi algorithm and parameter estimation is demonstrated by the EM algorithm. The last block-wise structure considered is a Multiresolution HMM and the chapter finishes off with some block-wise image processing applications such as aerial segmentation and feature extraction.

In conclusion, this book was very thorough, both mathematically and descriptively. If someone who is particularly interested in image processing and its applications desires a reference for the various techniques and mathematical models that can be used for digital images, this book will serve as an excellent resource. As a first year Master of Applied Science student in Electrical and Computer Engineering, I did find the book a little beyond my mathematical scope; however, I still have learnt a lot about stochastic image processing from it and found this to be an overall valuable experience.

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