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Computer Vision Beyond the Visible Spectrum

With 156 Figures

Springer

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Preface

Traditionally, computer vision has focused on the visible band for a variety of reasons. The visible band sensors are cheap and easily available. They are also sensitive in the same electromagnetic band as the human eye, which makes the produced data more interesting from the psychophysiology point of view. In fact, computer vision was pre-occupied for a long time with the problem of understanding and imitating the human visual system. Recently, this obsession subsided and computer vision research focused more on solving particular application problems with or without the help of the human visual paradigm. A case in point is the significant progress achieved in object tracking.

It so happens that many imaging applications cannot be addressed in the visible band. For example, visible sensors cannot see in the dark; thus, they are not very useful in military applications. Visible radiation cannot penetrate the human body and, therefore, cannot be a viable medical imaging modality. Other electromagnetic bands and sensor modalities have been identified and developed over the years that can solve all these problems, which are beyond the reach of the visible spectrum. Initially, it was primarily phenomenological and sensory work that was taking place. Later came algorithmic work, and with that computer vision beyond the visible spectrum was born.

In this book, we explore the state-of-the-art in *Computer Vision Beyond the Visible Spectrum (CVBVS)* research. The book is composed of nine chapters which are organized around three application axes:

1. Military applications with an emphasis on object detection, tracking, and recognition.
2. Biometric applications with an emphasis on face recognition.
3. Medical applications with an emphasis on image analysis and visualization.

Although the chapters describe research, they are not written as typical research papers. They have a tutorial flavor appropriate for a book.

The book opens with the military applications since they represent the birthplace of CVBVS. All the major modalities used in military applications are represented in the first five chapters. These include SAR (Synthetic Aperture Radar), laser radar, hyperspectral, and infrared. The first five chapters also address fundamental issues with regard to object detection, tracking, and recognition, sometimes in more than one modality. This allows comparative evaluation of these important computational imaging questions across the electromagnetic spectrum.

In Chapter 1, Boshra and Bhanu et al. describe a theoretical framework for predicting the performance of object (target) recognition methods. The issue of identifying military targets in imagery is of great importance in military affairs. For years, target recognition was based purely on heuristics, and as a result performance was brittle. Boshra and Bhanu's work is representative of a more rigorous methodological approach, which promises to transform target recognition from art to science.

In Chapter 2, Bhanu and Jones unveil specific methods for improving the performance of an SAR target recognition system. SAR is probably the most successful imaging modality for military applications, because of its all-weather capability. Bhanu and Jones' methods conform to the model-based framework and involve incorporation of additional features, exploitation of a priori knowledge, and integration of multiple recognizers.

In Chapter 3, Arnold et al. present target recognition methods in a different modality, namely, three-dimensional laser radar. Three-dimensional laser radars measure the geometric shape of targets. The main approach described in this chapter is quite appealing because it bypasses detection and segmentation processes.

In Chapter 4, Kwon et al. deal with target recognition in the context of hyperspectral imagery. The basic premise of hyperspectral target recognition is that the spectral signatures of target materials are measurably different than background materials. Therefore, it is assumed that each relevant material, characterized by its own distinctive spectral reflectance or emission, can be identified among a group of materials based on spectral analysis of the hyperspectral data. Kwon et al. use independent component analysis (ICA) to generate a target spectral template. ICA is a method well-suited to the modular character of hyperspectral imagery.

In Chapter 5, Vaswani et al. close the sequence of military application papers by presenting a method for object detection and compression in infrared imagery. The proposed solution is guided by the limitations of the target platform, which is an infrared camera with on-board chip. The object detection method is computationally efficient, to deal with the limited processing power of the on-board chip. It is also paired with a compression scheme to facilitate data transmission.

Chapter 6 deals with biometrics and signals a transition from the military to civilian security applications. Wolff et al. present a face recognition approach based on infrared imaging. Infrared has advantages over visible imaging for face recognition, especially in the presence of variable lighting conditions.

Wolff et al. provide quantitative support for this argument by unveiling a system that performs comparative evaluation.

Chapter 7 opens the medical applications part of the book. It refers to cardiovascular image analysis of magnetic resonance imagery (MRI). While SAR is probably the most successful modality for military applications, one could make the case that MRI is the most successful modality for medical applications. Initially, MRI was treated much like x-rays. A radiologist, without any machine assistance, was interpreting the raw imagery. Increasingly, however, computer vision methods aid in this interpretation. In this chapter, Sonka et al. present techniques for 3D segmentation and quantitative assessment of left and right cardiac ventricles, arterial and venous trees, and arterial plaques.

In Chapter 8, Fenster et al. present segmentation and visualization techniques in another very important medical imaging modality, that is, ultrasound. Specifically, the authors describe methods to reconstruct ultrasound information into 3D images to facilitate interactive viewing. They also describe automated and semi-automated segmentation methods to quantify organ and pathology volume for monitoring disease.

In Chapter 9, Berry et al. introduce some very interesting image analysis work on a novel medical imaging modality, namely, terahertz pulsed imaging. Vis-a-vis the more established MRI and ultrasound modalities, terahertz pulsed imaging is the "new kid on the block". Berry et al. propose Fourier transforms and wavelets to analyze spectroscopic information of materials. They actually demonstrate that these methods perform as well as traditional analysis methods for material properties and predict a number of biomedical applications that stand to benefit form this technology.

The book can be used for instruction in graduate seminars or as a reference for the independent researcher. Although CVBVS is a broad and fast moving field, the balanced selection of key theoretical and practical issues represented in the chapters of the book will maintain their relevance for some time. It is our sincere hope that the book will serve as a springboard for the individual researcher who is interested in CVBVS research.

A number of people have contributed in our effort and we are deeply grateful to all of them. These certainly include the authors of the individual chapters and the reviewers who patiently went through three review cycles. We are especially grateful to Pradeep Buddharaju who handled most of the last minute editing and thanks to whom the book assumed its finished form.

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