Preface

Within the last two decades, we have noticed improvement in the performance of face recognition (FR) systems in controlled conditions, characterized by suitable lighting and favorable acquisition distances. However, over the years, the technology has steadily progressed to tackling increasingly more realistic conditions rather than adequately handling only well-controlled imagery. Most related research emphasizes the maintenance of high recognition performance, while coping with increased levels of image variability. Among the most insidious problems of visible-spectrum-based face recognition algorithms are (a) the variation in level and nature of illumination, (b) the fact that as the level of illumination decreases, the signal-to-noise ratio rises quickly, and thus, automatic processing and recognition become very difficult, and (c) dealing with degraded face images acquired at operational conditions, including nighttime and long stand-off distances.

In order to address these issues, recent research has moved into the use of infrared (IR) imagery, namely intensified near infrared (NIR), shortwave IR (SWIR), middle wave IR (MWIR), and long wave IR (LWIR). Hence, in recent years, we see an increase of face recognition applications, especially those related to security and identity verification in the digital world, where different spectral bands are used. Certain FR applications are focused on *same-spectral band face matching* (i.e., matching either visible against visible, or IR against IR face images), while other applications are focused on *cross-spectral band face* (i.e., matching IR face images against their visible counterparts). In fact, what we notice, especially over the last decade, is a significant progress in the area of face recognition across the imaging spectrum, owing to advances in imaging sensors and optics, and the fact that the cost of IR cameras has dropped considerably. For example, the cost of some good quality IR imaging sensors is now comparable to high-end, digital, single-lens reflex (DSLR) cameras (visible band). In addition, we see significant advances in computer vision techniques used for the preprocessing of multi-band face (plus ocular and/or iris) images, including techniques related to the modeling and analysis of such images. Therefore, the problem of designing and developing reliable face

recognition systems across the imaging spectrum continues to offer a great challenge to computer vision and pattern recognition researchers.

There are two primary motivations that this book was based upon. The *firstmotivation* is the need for the development of efficient multispectral FR or FR-related algorithms and systems that can be reliably used in operational environments. The *secondmotivation* is the recent increased interest in research on face recognition-related technologies and the recent advances in computer vision, pattern recognition, and automated analysis, when using images of different biometric modalities, including face, periocular, and iris, from various parts of the imaging spectrum. The aforementioned motivations were identified when designing the original book structure and, as a result, helped in finding extraordinary researchers in the greater field of face recognition that could contribute with their book chapters.

The book is intended for biometrics researchers, including practitioners and students who either work or plan to become familiar with understanding and processing single-spectral, multispectral, or hyperspectral face images—when captured under controlled or uncontrolled environments, using a variety of imaging sensors, ranging from the state-of-the-art visible and infrared imaging sensors, to the usage of RGB-D and mobile phone image sensors.

The book provides various references for image processing, computer vision, biometrics, and security-focused researchers. The material provides information on current technology including discussion on research areas related to the spectral imaging of human skin, data collection activities, processing and analysis of multispectral and hyperspectral face and iris images, processing of mug shots from ID documents, mobile- and 3D-based face recognition, spoofing attacks, image alterations, score normalization techniques, and multispectral ocular biometrics.

More specifically, the book consists of 15 chapters, covering the aforementioned material, and discusses different components that can affect operational face recognition systems. Each chapter focuses on a specific topic, discussing background information, offering a literature review, presenting methodological approaches, experiments, and results, and, finally, concluding by pointing out challenges and future directions.

Chapter 1 provides an introduction to the interaction of energy in the electromagnetic spectrum with human tissue and other materials, the fundamentals of sensors and data collection, common analysis techniques, and the interpretation of results for decision making. The basic information provided in this chapter can be utilized for a wide range of applications where spectral imaging may be adopted, including face recognition.

Chapters 2 and 3 cover topics related to data collection of multispectral and hyperspectral face images. Chapter 2 details "best practice" collection methodologies developed to compile large-scale datasets of both visible and SWIR face images. All aspects of data collection are provided, from IRB preparation through data post-processing, along with instrumentation layouts for indoor and outdoor live capture setups. Details of past collections performed at West Virginia University to compile multispectral biometric datasets, such as age, gender, and ethnicity of the subject populations, are included. Insight is also given on the impact of collection

parameters on the general quality of images collected, as well as on how these parameters impact design decisions at the level of algorithmic development.

Chapter 3 discusses that spectral imaging offers a means to overcome several major challenges specific to current FR systems. The authors review four publically available hyperspectral face databases (CMU, PolyU-HSFD, IRIS-M, and Stanford) toward providing information on the key points of each of the considered databases. In addition, a new hyperspectral face database is introduced (IRIS-HFD-2014) that can serve as a benchmark for statistically evaluating the performance of current and future hyperspectral FR algorithms.

Chapters 4–7 cover topics related to challenging face-based identification technologies when processing visible and different infrared face images. Chapter 4 discusses two thermal-to-visible FR algorithms, as well as the preprocessing and feature extraction techniques used to correlate the signatures in the feature subspace. The chapter presents recognition results on an extensive multimodal face dataset containing facial imagery acquired under different experimental conditions. Furthermore, it discusses key findings and implications for MWIR-to-visible and LWIR-to-visible FR. Finally, it presents a novel imaging technique for acquiring an unprecedented level of facial detail in thermal images, polarimetric LWIR, along with a framework for performing cross-spectral face recognition.

Chapter 6 introduces a methodology to explore the sensitivities of a facial recognition imaging system to blur, noise, and turbulence effects. Using a government-owned and an open-source facial recognition algorithm, system performance is evaluated under different optical blurs, sensor noises, and turbulence conditions. The ramifications of these results on the design of long-range facial recognition systems are also discussed.

Chapter 7 provides a thorough understanding of challenges in thermal face detection, along with an experimental evaluation of traditional approaches. Further, the authors adapt the AdaBoost face detector to yield improved performance on face detection in thermal images in both indoor and outdoor environments. They also propose a region of interest selection approach, designed specifically for aiding occluded or disguised thermal face detection. The results suggest that while thermal face detection in semi-controlled environments is relatively easy, occlusion and disguise are challenges that require further attention.

Chapter 8 provides an overview of spoofing attacks and spoofing countermeasures for FR systems, with a focus on visual spectrum systems in 2D and 3D, as well as near-infrared (NIR) and multispectral systems. The authors cover the existing types of spoofing attacks and report on their success to bypass several state-of-the-art FR systems. Experimental results show that spoofing attacks present a significant security risk for FR systems in any part of the spectrum. The risk is partially reduced when using multispectral systems. Finally, the authors provide a systematic overview of the existing anti-spoofing techniques, with an analysis of their advantages and limitations and prospective for future work.

Chapter 9 discuss that when face images are captured under desirable conditions, some intentional or unintentional face image alterations can significantly affect the recognition performance. In particular, in scenarios where the user template is created from printed photographs rather than from images acquired live during enrollment (e.g., identity documents), digital image alterations can severely affect the recognition results. In this chapter, the authors analyze both the effects of such alterations on face recognition algorithms and the human capabilities to deal with altered images.

Chapter 10 starts by discussing the factors impacting the quality of degraded face photographs from ID documents. These include mainly hairstyle, pose and expression variations, and lamination and security watermarks. Then, the authors focus on investigating a set of methodological approaches in order to be able to overcome most of the aforementioned limitations and achieve a high identification rate. They incorporate a combination of preprocessing and heterogeneous face matching techniques, where comparisons are made between the original (degraded) photograph, the restored photograph, and the high-quality photograph (mug shots). The proposed restoration approaches discussed in this chapter can be directly applied to operational scenarios that include border-crossing stations and various transit centers.

Chapter 11 deals with FR in mobile and other challenging environments, where both still images and video sequences are examined. The authors provide an experimental study of one commercial off-the-shelf and four recent open-source FR algorithms. Experiments are performed on several freely available challenging still image and video face databases, including one mobile database, always following the evaluation protocols that are attached to the databases. The authors supply an easily extensible open-source toolbox to rerun all the experiments, which includes the modeling techniques, the evaluation protocols, and the metrics used in the experiments, and provide a detailed description on how to regenerate the results.

Chapter 12 discusses existing RGB-D face recognition algorithms and presents a state-of-the-art algorithm based on extracting discriminatory features using entropy and saliency from RGB-D images. The authors also present an overview of available RGB-D face datasets along with the experimental results and analysis to understand the various facets of RGB-D face recognition.

Chapter 13 highlights both the advantages and disadvantages of 2D- and 3D-based face recognition algorithms. It also explores the advantages of blending 2D and 3D databased techniques, also proposing a novel approach for a fast and robust matching. Several experimental results, obtained from publicly available datasets, currently at the state of the art, demonstrate the effectiveness of the proposed approach.

Chapter 14 first introduces the reader to the concept of score normalization. Then, it discusses why methods of normalizing matching scores are an effective and efficient way of exploiting score distributions and when such methods are expected to work. The first section highlights the importance of normalizing matching scores and offers intuitive examples to demonstrate how variations between different biometric samples, modality components, and subjects degrade recognition

performance. It also answers the question of why score normalization effectively utilizes score distributions. The next three sections offer a review of score normalization methods developed to address each type of variation. The chapter concludes with a discussion of why such methods have not gained popularity in the research community and answers the question of when and how one should use score normalization.

Chapter 15 discusses the use of multispectral imaging to perform bimodal ocular recognition, where the eye region of the face is used for recognizing individuals. In particular, it explores the possibility of utilizing the patterns evident in the sclera, along with the iris, in order to improve the robustness of iris recognition systems. The work discusses the assembly of a multispectral eye image collection to study the impact of intra-class variation on sclera recognition performance. Then, the authors discuss the design and development of an automatic sclera, iris, and pupil segmentation algorithm, before, finally, they demonstrate the improvement of iris recognition performance by fusing the iris and scleral patterns in non-frontal images of the eye.

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Book Chapters Evaluation Process

Each book chapter was accepted after an extensive peer-reviewed process. First, the original abstracts submitted by the authors were reviewed. Then, each conditionally accepted chapter was assigned to 2–4 members of the editorial board, including the editor's independent review and meta-review. After the first rebuttal, the authors of each book chapter addressed all comments of the original review process and they submitted an updated draft. Next, each book chapter was reviewed and updated one more time before it was finally accepted.

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