Preface

With a very security-conscious society, biometrics-based authentication and identification have become the focus of many important applications as it is widely believed that biometrics can provide accurate and reliable identification. Biometrics research and technology continue to mature rapidly, driven by pressing industrial and government needs and supported by industrial and government funding. As the number and types of biometrics architectures, sensors, and techniques increases, the need to disseminate research results increases as well.

Advanced deep learning capabilities, and deep convolutional neural networks (CNN) in particular, are significantly advancing the state of the art in computer vision and pattern recognition. The deep CNN is a biologically inspired variant of multilayer perceptron and represents a typical deep learning architecture.

Since 2006, we have organized a series of high-quality Annual Biometrics Workshops under the auspices of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR). This series has emerged as the premier forum for showcasing cutting-edge research from academia, industry, and government laboratories. During the past few years the CNN-based techniques, as evidenced by the increasing number of papers at CVPR and the biometrics workshop, have shown strong ability to learn effective feature representation from input data, especially for the perceptual and biometrics-related tasks.

The book is based on a selection of topics and authors from the proceedings of the 2016 biometrics workshop and a general call for chapters to the computer vision, pattern recognition, and the biometrics communities at large. The selection of chapters in this book is made after two rounds of rigorous review process.

Outline of the Book and Chapter Synopsis

Many of the biometrics applications require the highest level of accuracy that is being made available with the advanced deep learning capabilities. This book addresses many aspects of biometrics research issues relating to different biometrics modalities with the sole goal of improving performance for the biometrics identification. A brief and orderly introduction to the chapters is provided in the following.

The book chapters in this book on *Deep Learning for Biometrics* are organized under four major parts. **Part I** deals with deep learning for face biometrics and it includes three chapters on this topic in the book.

Chapter 1 by Grill-Spector, Kay, and Weiner on the functional neuroanatomy of face processing: insights from neuroimaging and implications for deep learning provides insightful details on the connections between currently popular deep neural network architectures for the biometrics and neural architectures in the human brain. The authors in this chapter detail a range of findings from the neuroimaging techniques on the anatomical features of the face network and the computations performed by the face-selective regions in the human brain. These empirical findings can lead to more accurate deep neural networks for face recognition.

One of the challenges related to the applications of the deep learning-based biometrics solutions is the computational complexity of the selected network. Many applications of face recognition demand highly efficient search capabilities from the large databases and in a database which requires smaller template size and faster template-matching capabilities.

Chapter 2 by Vizilter, Gorbatsevich, Vorotnikov, and Kostromov on real-time face identification via a multi-convolutional neural network and boosted hashing forest describes the development of boosted hashing-based real-time face recognition system using convolutional neural networks. This chapter presents a new biometric-specific objective function for the binary hashing that enables joint optimization of the face verification and identification.

Despite significant improvement in the accuracy of the face detection algorithms in the past decade, their accuracy is still far from that displayed by humans, particularly for the images acquired under challenging imaging environments, like with large occlusions or off-poses. Therefore, Chap. 3 by Zhu, Zheng, Luu, and Savvides on CMS-RCNN: contextual multi-scale region-based CNN for unconstrained face detection introduces a new architecture, a contextual multi-scale region-based CNN, to accurately detect human faces from a complex background and under challenging imaging conditions.

Part II of the book deals with deep learning for fingerprint, finger vein, and iris recognition. It includes three chapters that are described below.

Some of the challenging open problems in the fingerprint identification are related to accurately segmenting latent fingerprint images. Chapter 4 by Ezeobiejesi and Bhanu on latent fingerprint image segmentation using deep neural networks describes how deep neural networks can be employed to accurately segment latent fingerprint regions from complex image backgrounds. The authors present a latent fingerprint image patch and noise image patch-based classification strategy that outperforms the results on publicly available latent fingerprint databases.

Vascular biometrics identification has attracted several applications and is believed to significantly improve the integrity of biometrics systems, while preserving the privacy of an individual during authentication. Chapter 5 by Xie and Kumar on finger vein identification using convolutional neural networks and supervised discrete hashing presents a detailed deep learning-based investigation into finger vein identification. The development of competing deep learning-based solutions that can be operational using limited training data is among one of the open challenges in biometrics. Biometrics modalities like finger vein have very limited dataset in the public domain, primarily due to enhanced privacy concerns and/or due to cooperative imaging requirements. The experimental results presented in this chapter, using publicly available but limited two-session dataset indicate promises from supervised discrete hashing and provide insights into the comparative performance with state-of-the-art methods for finger vein identification.

Almost all the iris recognition systems deployed today operate using stop and stare mode. Such systems operate in constrained imaging environment and deliver remarkable accuracy. Application of iris recognition technologies for surveillance and at-a-distance applications require accurate segmentation capabilities from such images acquired with visible and near-infrared illuminations. Chapter 6 by Jalilian and Uhl on iris segmentation using fully convolutional encoder–decoder networks details the segmentation of challenging iris images using fully convolutional encoder–decoder networks.

Part III of the book deals with deep learning for soft biometrics and it includes four interesting chapters on this topic.

Accurate identification of soft biometrics features is vital for improving the accuracy of biometrics-based surveillance systems. Chapter 7 by Wu, Chen, Ishwar, and Konrad on two-stream CNNs for gesture-based verification and identification: learning user style details a deep learning framework that simultaneously leverages on the spatial and temporal information in video sequences. The experimental results presented by the authors for the identification and verification on two biometrics-oriented gesture datasets indicate results that outperform the state-of-art methods in the literature.

Developing accurate capabilities to automatically detect the soft biometrics features, like the gender, from the low resolution, off angle, and occluded face images is highly desirable for a range of biometrics applications. Chapter 8 by Juefei-Xu, Verma, and Savvides is on DeepGender2: a generative approach toward occlusion and low-resolution robust facial gender classification via progressively trained attention shift convolutional neural networks (PTAS-CNN) and deep convolutional generative adversarial networks (DCGAN). It describes the development of a deep learning-based gender classification approach. The authors describe how a progressive training strategy and the deep generative approach to recover the missing pixels can achieve excellent results for the gender classification using occluded face images.

Chapter 9 by Tapia and Aravena is on gender classification from near-infrared (NIR) iris images using deep learning. Like the previous chapter, it is also devoted to the gender classification problem but using NIR iris images. Such images are typically available during the iris acquisition and authors use a pretrained deep belief network to identify gender from these images.

Several law enforcement departments use tattoos to identify the personal beliefs and characteristics, similar to many popular soft biometrics features. Chapter 10 by Di and Patel on deep learning for tattoo recognition describes how the Siamese networks with the conventional triplet function can be used to identify tattoos in publicly available databases, with very good results.

Part IV of the book deals with deep learning for biometrics security and template protection and it consists of two chapters.

Ensuring the security of biometrics templates and the systems is an integral part of biometrics infrastructure. Chapter 11 by Pandey, Zhou, Kota, and Govindaraju on learning representations for cryptographic hash-based face template protection introduces challenges and the techniques for the protection of biometrics template. The authors in this chapter introduce template representations that are learned by CNN for the cryptographic hash-based protection of face image templates.

The last chapter in this book, i.e., Chap. 12 by Pala and Bhanu on deep triplet embedding representations for liveness detection considers widely discussed problems relating to the protection of biometrics systems against fake biometrics samples. The authors introduce a metric learning strategy that uses a variant of triplet loss function to identify fake fingerprints in image patches. Experimental results presented on publicly available database indicate outperforming state-of-the-art results from this deep learning-based strategy.

Challenges for the Future

A brief summary of the book chapters in the above paragraphs indicates that there has been significant interest in the advancement of biometrics technologies using the deep learning architectures. The work underlines challenges in deep learning when the training sample size available from a particular biometrics modality is quite small. Several authors have underlined that the factors that most influence the accuracy from deep neural networks is the depth of the network, pretraining, and the data augmentation in terms of random crops and rotations.

Several classical biometrics feature extraction and matching algorithms work very well when the images are acquired under relatively constrained environments, e.g., fingerprint and iris, with no constraints on the need for huge training samples. It is unclear how learned deep neural networks could aid, improve, or replace such popular classical methods that have been matured in past three decades, like the popular *iriscode*-based iris recognition or the minutiae matching-based fingerprint recognition widely deployed today. In this context, it is important that emerging deep learning based algorithms for biometrics should also present careful performance comparisons, on public datasets using appropriate protocols, and under open set environments or cross-dataset evaluations to make a convincing case for the benefits of biometrics community in academia, industry, and the Government.

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