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Chapter 1

Introductory Chapter: Face Recognition - Overview, Dimensionality Reduction, and Evaluation Methods

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Face recognition is one of most popular and powerful applications in modern computing industries [1–4]. It has found applications ranging from person identification (surveillance) [5] to emotion identification (human–machine interaction) [6]. Over the past few decades, researchers in field of computers and electrical and electronics engineering have worked continuously to improve the performances of the face recognition systems. In-spite of these continuous efforts, there are still a plenty of scope for the new and additional research in the field of face recognition. This is due to the popularization of light-weight computing devices, increased customer expectations, and business competitions.

Now the world best cameras in terms of resolution are available in smart phones at affordable price, and CCD cameras are found even in houses and almost in all commercial, business, and office environments including small-sized enterprises. Amount of face images being captured keep on increasing, and recognition of faces among these huge databases makes the task further challenging. One of most the important subtopics in face recognition is dimensionality reduction [1], because storing and processing of these high-resolution face images from huge database using light-weight devices require dimensionality reduction.

Several different face recognition systems, including hardware (cameras, memory disk, and processors) and software, are available in the market. These face recognition systems provide better performance in one aspect and lack in other aspect. Comprehensive evaluation the performances of face recognition systems is the need of the hour.

Keeping these factors in mind, this book on "face recognition" is focusing on dimensionality reduction and evaluation methods. This book is brief but comprehensive. Other than this introductory chapter, this book has four more chapters, two chapters for dimensionality reduction and one for an overview of the face recognition systems and evaluation methods.

Rest of this introductory chapter is spared for providing a brief outlines, linkages, importance, and significances of the four chapters of this book.

Chapter 1: This chapter provides an overview of face recognition, various issues in face recognition, and different methods of face recognition and applications of face recognition. We strongly encourage the young readers to thoroughly study this chapter to get the bird's eye view of face recognition. Advanced readers can proceed to Chapter 2 directly.

Typical complex engineering applications requires various submodules and proper fine tuning of all those modules to make the application perfect. Face recognition, one of the toughest complex engineering applications, certainly requires number of submodules. A few important submodules are pre-processing, face detection and normalization, feature database and classifier. These building blocks are presented in Chapter 1 in a simple way. Various challenges in face recognition include [7–10]: scale invariance, rotation invariance, translation invariance, illumination invariance, and emotion invariance. All these make the task difficult for the face recognition system. These challenges are discussed in Chapter 1.

Authors of Chapter 1 presented a comprehensive overview of various classical face recognition methods. Classification of 18 different classical face recognition algorithms based on local and holistic features is also presented in this chapter nicely. Over and above, the classical face recognition methods and modern face recognition methods are briefly introduced in Chapter 1. Modern techniques include artificial neural networks, wavelets-based methods, descriptor-based method, 3D methods, and video-based techniques. Advantages and disadvantages of both classical and modern methods are narrated in Chapter 1. This will help the students to choose an appropriate technique for doing their projects. Eight different potential applications of face recognition systems are highlighted in Chapter 1. Ideally, through reading of Chapter 1 will be of immense help for the young readers.

Chapter 2: Traditional pattern recognition methods can either be a supervised learning or unsupervised learning. Face recognition methods comes under supervised learning methods. Supervised learning requires proper and complete labeling of all patterns and objects. Due to social media and in general internet, the amount of face images being generated is steeply increasing. Most of these face images are not labeled by required for the face recognition system to provide satisfactory performance. Hence, a new type of learning method, which is a subtype of supervised leaning called, semi-supervised learning method is being applied to modern face recognition methods [11–16]. This chapter is dealing with this new learning method and also addressing dimensionality reduction concept in semi-supervised learning.

Semi-supervised learning methods can be grouped under transductive learning or induction learning. Authors of this chapter have systematically presented the state-of-the-art methods and nicely introduced their contribution in this chapter. Authors of Chapter 2 have proposed a new and effective algorithm for semi-supervised dimensionality using local and global regression. The algorithm proposed in this chapter is capable of reducing dimensions of both transductive learning and induction learning. Proposed algorithm is explained from the first principles so that the readers with pattern recognition or image processing background can easily understand and apply this in their projects. Presentation of the proposed algorithm is

excellent as it has proper mix of analytical and descriptive treatments. Theorems employed by the authors are also provided and over and above the proposed concepts are illustrated with intermediate results. This is a must read subsection for the young learners.

In addition to the smooth and neat presentation of the proposal and related works, the authors of Chapter 2 have conducted extensive experiments and beautifully presented the results along with appropriate discussions. Experiments are conducted not only using synthetic dataset but also using three of the real-world bench mark datasets, namely UMNIST, extended Yale B, and MIT-CBCL. Experimental results are also compared with existing methods. This chapter is well written and much useful for the both young and senior researchers working in pattern recognition.

Chapter 3: Among the various challenges of a typical pattern recognition system, dimensionality reduction is one of important tasks. Image processing applications such as face recognition should focus on dimensionality reduction for better performance. Subspace projection techniques are highly useful and classical option in face recognition is useful for reducing the dimension. Principle component analysis (PCA) and linear discriminant analysis (LDA) are both popular and powerful subspace projection techniques over the past few decades [17] and applied in almost all pattern recognition systems [18–26].

In face recognition, input–output pairs are known as it is mostly supervised. Here, linear regression that used to fit a linear function to a set of input–output pairs is latest technique and also comes under subspace projection. Chapter 3 is focusing on latest technique named linear regression and its variants, over and above the classical subspace projection techniques. Important and critical issues in face recognition, namely partial occlusion, illumination variance, different expression, pose variance, and low resolution are all addressed and presented.

This chapter is self-contained and comprehensive. Authors of this chapter have provided a brief overview of how face images are represented and recognized. Two of the classical subspace projection methods, namely PCA and LDA are briefly presented in this chapter. This quick introduction will help even advanced readers to recall the basics. In addition to this similarity metrics used in the classifier stage of face recognition systems are also presented.

Various latest subspace optimization techniques, namely linear regression classification, robust linear regression classification, improved principal component regression, unitary regression classification, linear discriminant regression classification, generalized linear regression classification, and trimmed linear regression are all presented. These eight methods are discussed in this chapter with correct blend of mathematical equations and theoretical descriptions.

Authors have conducted extensive experiments are presented the results. Performance analysis is carried out on the benchmark datasets, namely Yale B, AR, FERT, and FEI. Comparative analysis of the various subspace projection methods and linear regression and its variants are also provided precisely in this chapter. This chapter is self-reliant and will be useful to both young and advanced readers.

Chapter 4: Performance evaluation is one of most important aspects in face recognition applications [2, 3, 27–29]. Recognition rate (or classification accuracy) is the commonly used metrics to analyze the performance of the face recognition methods. But there are several other important and critical metrics available for performance evaluation of the system. In this chapter, those metrics are presented and demonstrated. A brief outline of face recognition techniques and methods are provided in this chapter. Four important component of a confusion matrix, namely true positive, true negative, false positive, and false negative are presented. Based on these four parameters, seven significant evaluation metrics, namely precision, recall, sensitivity, specificity, fallout, error rate, and accuracy are presented in this chapter. Receiver operating characteristics (ROC) curve analysis is presented sensitivity and specificity. Salient points in ROC analysis are illustrated clearly for all possible performances of face recognition methods.

Like ROC combines sensitivity and specificity, F-score combines precision and recall, and this metric is better explained in this chapter. In addition to these metrics, the following metrics are also briefed: false match rate, false non-match rate, equal error rate, failure to enroll rate, and failure to capture rate.

Authors of this chapter have conducted experiments to analyze the performances of the face recognition using these metrics. Three different case studies are presented using face images from the benchmark datasets. Whoever developing face recognition system finds this chapter useful.

Final word: This book has five chapters including this introductory. This book can be a brief material and will be highly useful for students, researchers, and practicing engineering working in pattern recognition, image processing, and machine vision.

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