Illumination Invariant Face Recognition by Non-Local Smoothing

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Abstract. Existing face recognition techniques struggle with their performance when identities have to be determined (recognized) based on image data captured under challenging illumination conditions. To overcome the susceptibility of the existing techniques to illumination variations numerous normalization techniques have been proposed in the literature. These normalization techniques, however, still exhibit some shortcomings and, thus, offer room for improvement. In this paper we identify the most important weaknesses of the commonly adopted illumination normalization techniques and presents two novel approaches which make use of the recently proposed non-local means algorithm. We assess the performance of the proposed techniques on the YaleB face database and report preliminary results.

Keywords: Face recognition, retinex theory, non-local means, illumination invariance.

1 Introduction

The performance of current face recognition technology with image data captured in controlled conditions has reached a level which allows for its deployment in a wide variety of applications. These applications typically ensure controlled conditions for the image acquisition procedure and, hence, minimize the variability in the appearance of different (facial) images of a given individual. However, when employed on facial images captured in uncontrolled and unconstrained environments the majority of existing face recognition techniques still exhibits a significant drop in their recognition performance.

The reason for the deterioration in the recognition (or verification) rates can be found in the appearance variations induced by various environmental factors, among which illumination is undoubtedly one of the most important. The importance of illumination was highlighted in several empirical studies where it was shown that the illumination induced variability in facial images is often larger than the variability induced to the facial images by the individual's identity [1]. Due to this susceptibility, numerous techniques have been proposed in

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the literature to cope with the problem of illumination. These techniques try to tackle the illumination induced appearance variations at one of the following three levels: *(i)* at the pre-processing level, *(ii)* at the feature extraction level, and *(iii)* at the modeling or/and classification level.

While techniques from the latter two levels represent valid efforts in solving the problem of illumination invariant face recognition, techniques operating at the pre-processing level exhibit some important advantages which make them a preferred choice when devising robust face recognition systems. One of their most essential advantages lies in the fact that they make no assumptions regarding the size and characteristics of the training set while offering a computationally simple and simultaneously effective way of achieving illumination invariant face recognition.

Examples of normalization techniques operating at the pre-processing level[1] include the single and multi scale retinex algorithms [2],[3], the self quotient image [4], anisotropic smoothing [5], etc. All of these techniques share a common theoretical foundation and exhibit some strengths as well as some weaknesses. In this paper we identify (in our opinion) the most important weaknesses of the existing normalization techniques and propose two novel techniques which try to overcome them. We assess the proposed techniques on the YaleB database and present encouraging preliminary results.

The rest of the paper is organized as follows. In Section 2 the theory underlying the majority of photometric normalization techniques is briefly reviewed and some weakness of existing techniques are pointed out. The novel normalization techniques are presented in Section 3 and experimentally evaluated in Section 4. The paper concludes with some final comments in Section 5.

2 Background and Related Work

The theoretical foundation of the majority of existing photometric normalization techniques can be linked to the Retinex theory developed and presented by Land and McCann in [6]. The theory tries to explain the basic principles governing the process of image formation and/or scene perception and states that an image $I(x, y)$ can be modeled as the product of the reflectance $R(x, y)$ and luminance $L(x, y)$ functions:

$$I(x, y) = R(x, y)L(x, y). \quad (1)$$

Here, the reflectance $R(x, y)$ relates to the characteristics of the objects comprising the scene of an image and is dependant on the reflectivity (or albedo) of the scenes surfaces [7], while the luminance $L(x, y)$ is determined by the illumination source and relates to the amount of illumination falling on the observed scene.

Since the reflectance $R(x, y)$ relates solely to the objects in an image, it is obvious that (when successfully estimated) it acts as an illumination invariant representation of the input image. Unfortunately, estimating the reflectance from

[1] We will refer to these techniques as photometric normalization techniques in the remainder of this paper.