Facial Expression Recognition Using Binary Pattern and Embedded Hidden Markov Model

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Abstract. This paper proposes a robust facial expression recognition approach using an enhanced center-symmetric local binary pattern (ECS-LBP) and embedded hidden Markov model (EHMM). The ECS-LBP operator encodes the texture information of a local face region by emphasizing diagonal components of a previous center-symmetric local binary pattern (CS-LBP). Here, the diagonal components are emphasized because facial textures along the diagonal direction contain much more information than those of other directions. Generally, feature extraction and categorization for facial expression recognition are the most key issue. To address this issue, we propose a method to combine ECS-LBP and EHMM, which is the key contribution of this paper. The performance evaluation of proposed method was performed with the CK facial expression database and the JAFFE database, and the proposed method showed performance improvements of 2.65% and 2.19% compared to conventional method using two-dimensional discrete cosine transform (2D-DCT) and EHMM for CK database and JAFFE database, respectively. Through the experimental results, we confirmed that the proposed approach is effective for facial expression recognition.

Keywords: Facial Expression Recognition, Binary Pattern, EHMM.

1 Introduction

A challenging research issue and one that has been of growing importance to those working on human-computer interactions are to endow a machine with an emotional intelligence. Such a system must be able to create an affective interaction with users: it must have the ability to perceive, interpret, express and regulate emotions [1]. In this case, recognizing the user's emotional state is one of the main requirements for computers to successfully interact with humans [2]. Facial expression recognition is one of the most powerful, natural and immediate means for human beings to communicate their emotions. Automatic facial expression analysis is an interesting and challenging problem, and impacts important applications in many areas such as human–computer interaction and data-driven animation. There are two common approaches to extract facial features: geometric feature-based methods and appearance-based methods. Geometric features present the shape and locations of facial components, which are extracted to form a feature vector that represents the face geometry. Facial action cod-

D. Hwang et al. (Eds.): ICCCI 2014, LNAI 8733, pp. 233–242, 2014.

ing system (FACS) introduced by Ekman and Friesen [3] is one of the most popular geometric feature-based methods that represents facial expression using a set of action units (AU), where each action unit corresponds to the physical behavior of a specific facial muscle. On the other hand, appearance-based methods employ image filter or filter bank on the whole face or some specific regions of the facial image in order to extract changes in facial appearance. Recently, facial expression analyses based on local binary pattern (LBP) [4] and its variants such as centralized binary pattern (CBP) [5] and CS-LBP [6] have gained much popularity for their superior performances.

In this paper, we propose a robust facial expression recognition approach using ECS-LBP and EHMM. In fact, the methodology using 2D-DCT and EHMM was previously employed in the face recognition fields. However, this paper applied the EHMM in a different manner for successful facial expression recognition. In particular, we devise a novel feature descriptor, i.e., enhanced center-symmetric local binary pattern (ECS-LBP), to achieve better performance compare to conventional features such as 2D-DCT, LBP, CBP and CS-LBP. The ECS-LBP descriptor is the modified binary pattern of emphasizing the diagonal component of previous CS-LBP to make a more illumination-robust binary pattern. Here, the diagonal components are emphasized because facial textures along the diagonal direction contain much more information than those of other directions. Consequently, we implemented a novel facial expression recognition system with ECS-LBP feature descriptor and EHMM. Performance evaluation of the proposed system was carried out using an extended Yale B database which consists of 2,414 face images for 38 subjects representing 64 illumination conditions under the frontal pose. In the experiments, we will demonstrate the effectiveness of the proposed approach by comparing it with various other approaches.

2 Feature Descriptor for Facial Expression Recognition

2.1 Conventional 2D-DCT

Two-dimensional discrete cosine transform has been employed in face recognition to reduce dimensionality. The advantage of 2D-DCT is that it is data independent. That is, the basis images are only dependent on one image instead of on the entire set of training images. It can be also implemented using a fast algorithm. Feature extraction of a face image using 2D-DCT consists of two steps [7].

In the first step, the face image is divided in small block images. Let $P \times L$ be the window size of 2D-DCT, and $Q \times M$ be the overlap size in the horizontal and vertical directions of the image. Then, the number of blocks is calculated by the following equation for an image with W rows and H columns.

$$T = \left(\frac{W-Q}{P-Q}\right) \times \left(\frac{H-M}{L-M}\right) \tag{1}$$

In the next step, the 2D-DCT coefficients of the image block $f(x, y)$ are calculated. If we assume that P and L are equal to N ($P = L = N$), then 2D-DCT coefficients, $C(u, v)$ is computed defined by