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Learning a Multiple Kernel Similarity Metric for kinship verification

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ABSTRACT

Kinship Verification (KV) has recently caught much attention in the computer vision community due to its potential applications ranging from missing children search to social media analysis. Most of the related work focuses either on developing hand-crafted feature representations to describe the faces or on learning the Mahalanobis distance metric to measure the similarity between facial images. Instead, in this paper, we propose a novel Multiple Kernel Similarity Metric (MKSM), in which, different from the Mahalanobis metric, the similarity computation is essentially based on an implicit nonlinear feature transformation. The overall MKSM is a weighted combination of basic similarities and therefore possesses the capacity for feature fusion. The basic similarities are derived from base kernels and local features, and the weights are obtained by solving a constrained linear programming (LP) problem that originates from a Large margin (LM) criterion. Particularly, the LM criterion not only guarantees the generalization on unseen samples when the training set is small, but also leads to sparsity in the weight vector which in turn boosts the efficiency at the prediction stage. Extensive experiments on four publicly available datasets demonstrate the effectiveness of the proposed method.

1. Introduction

The task of KV is to determine whether there exists a certain kind of kin relation between two people when their facial images are given. Potential applications include social media analysis with marketing purposes, family photos organization, finding missing family members, preventing child trafficking and forensics. To these ends, recently, different algorithms have been proposed to tackle various challenges. However, the performance is still far from satisfactory even on experimental datasets, let alone for real-world applications. The reason lies in the intrinsic difficulties of KV task, especially when the facial images are taken under unconstrained scenes. Firstly, different from face recognition, KV aims at identifying similar features between two different individuals. Thus, there would be greater variations on facial images caused by gender, age, and possible expressions and complexion. Secondly, the genetically driven similarities are very subtle and unstable (as the

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resemblance may be reflected in a variety of forms), and therefore cannot be easily captured under the usual similarity metrics or ordinary facial features. Thirdly, suffered from the applications, the facial images for KV are usually taken under different unconstrained scenarios which may reveal large difference in face pose, light condition and image resolutions. As a result, the difference of facial images with kin relation is usually significant and even larger than that of facial images without kin relation if the appearance similarity is measured by common features and generic metrics.

Kinship verification has become an active research area both in computer vision and biometrics since Fang et al. [8] first proposed to utilize computational methods for this challenging task. Related work includes learning distance/similarity metrics, training discriminative binary classifiers, as well as developing expressive hand-crafted features. However, most of the algorithms either focus only on learning a Mahalanobis distance metric or directly training binary classifiers from single-view feature representations. In contrast to the previous work, a novel MKSM method is proposed in this paper to overcome these shortcomings. Specifically, at the training stage, a bunch of local features are extracted from densely distributed facial image patches of different sizes and locations. Meanwhile, a group of nonlinear base kernels are provided for implicit feature transformation. Then, a set of base similarities can be produced for each pair of images, where different base similarities are derived from different (kernel, feature) pairs and they measure the resemblance of facial images from different local aspects. After that, the weights of base similarities are determined by solving an LP problem originated from the LM criterion by which the examples that violate the margin constraints will be penalized with hinge loss. Moreover, sparse weight vector could be obtained if the hyperparameters are properly set in the LP problem, which achieves the purpose of feature selection. The final similarity metric is actually a weighted sum of the selected base similarity metrics. At the verification stage, only the selected local features need to be computed and thus the efficiency can be improved. Extensive experiments show that the proposed MKSM method is comparable or superior to the majority of previous metric learning methods in the KV domain. To sum up, the major contributions of this work are elaborated as follows.

(1) The proposed MKSM method first applies the multiple kernel similarities (MKS), which cover a flexible family of linear and nonlinear metrics, to the KV problem. The MKS metric is more likely to capture the intrinsic resemblance between relatives than many of the existing methods, since these methods often restrict the parameterized metrics into a narrow family (usually a family of linear similarities) that fails to model the subtle resemblance sufficiently.
(2) Starting from the proposed LM criterion, the KV task is finally formulated as a constrained LP problem with $L1$ regularization which will lead to sparsity in the solution vector. The sparse solution provides the foundation for feature and kernel selection, and the feature selection not only reduces the computation cost at the prediction stage but also helps exclude the redundant information that may degrade the verification performance.
(3) The MKSM method is essentially performing the feature selection and metric learning simultaneously and jointly, and therefore it is more likely to produce a global optimal metric than many traditional methods which conduct the feature selection independently of and proceeding to the metric learning procedure.
(4) The proposed MKSM method provides a simple framework for metric learning and feature fusion/selection in the KV task. Extensive experiments demonstrate that, by using only a small number of local features, the proposed method could also achieve comparable or superior results compared with many state-of-the-art techniques.

The reminder of this paper is organized as follows. In Section 2, we present a brief review of the related work on KV task, including its biological basis, the frequently used features and the existing learning based methods. In Section 3, we describe the multi-kernel multi-feature similarity representation, and present a large margin learning method. Experiments on kinship verification and discussion on parameter analysis are conducted in Section 4. Finally, conclusion and future work are offered in Section 5.

2. Related work

In this section, we review the related work on the KV task from its biological basis, the frequently used features and the existing learning-based methods.

2.1. Kinship verification

The idea of conducting KV through biometric methods originates from the research in the anthropology/psychology communities. Relevant studies [18] have revealed that the biologically related persons are more likely to share similar facial appearance as the result of genetic overlap. This viewpoint suggests that human faces can be considered as an important biometric trait to identify kin relations. Inspired by this, computer vision scientists began to investigate KV problems from facial images in recent years. The most commonly investigated kin relations include father-son (F-S), father-daughter (F-D), mother-son (M-S), and mother-daughter (M-D). These kinship types are the closest biological relations due to largely shared genes [16]. Fig. 1 shows some facial image pairs with different kin relations from public dataset KFW [16] and TsKINFACE [20]. Note that some image pairs share high degree of similarites (the 1st row of Fig. 1a and b), whilst kinships in some other image pairs (the 2nd row of Fig. 1a) are very difficult to be verified even by human. Since the work in [8], diverse works have been devoted to this task using computer vision techniques and some encouraging progresses have been made. Generally speaking, the existing methods can be mainly classified into two categories, the feature based method and the learning based method. The feature-based methods aim to develop a hand-crafted feature representation so that the stable