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Kinship verification from facial images by scalable similarity fusion

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ABSTRACT

Kinship verification using face images (KVFI) is a relatively new and challenging problem in computer vision and biometrics, while kin relationship in psychology has been well studied over the past decades. Recent advances in KVFI have shown that learning an effective similarity metric plays a critical role in the verification problem. However, most existing distance metric learning (DML) based KVFI methods use batch learning techniques to seek an optimal kin similarity metric, making them less scalable in practical verification tasks. To address this, we propose in this paper a scalable similarity learning (SSL) method for KVFI. Unlike existing DML-based solutions, SSL aims to learn a diagonal bilinear similarity model by online truncated gradient learning, which enjoys superiority in scalability and computational efficiency for practical KVFI with high-dimensional data. We further derive a multiview SSL algorithm by optimal fusion of the diagonal similarity models from multiple feature representations in a coherent online process, such that the interactions and correlations in multiview kin data can be leveraged to obtain refined and high-level information. Empirically, we evaluate our proposed method on two benchmark datasets against the state-of-the-art DML-based solutions, and the results demonstrate that our method can achieve competitive or better verification performance, and enjoys the superiority in scalability and computational efficiency.

1. Introduction

The goal of kinship verification using face images (KVFI) is to determine whether a given pair of face images has a kinship relation. Recent evidence in psychology has indicated that face appearance is a reliable cue for measurement of the genetic similarity between children and their parents [1–4]. Motivated by this observation, KVFI has attracted more attention from computer vision and biometrics societies [5–18]. In practice, there exist some important and potential applications for KVFI, ranging from searching missing children to social media analysis [5,9,10,12]. Fig. 1 presents some face examples (with kin relations) from the KinFaceW dataset [12].

While some encouraging results have been achieved over the past five years [5–19], KVFI still remains open to further improvement. On one hand, face images are often captured in wild conditions, and varying illumination, poses and expressions in such scenarios make the verification problem quite challenging. On the other hand, kinship verification aims to investigate the kin relationship between two different visual entities (*e.g.*, mother and son), and hence the inherent appearance gap in kinship verification is generally much larger than that in traditional face recognition [24–33,38].

The existing methods for KVFI are either feature-based [5–7,10,14,16,18] or model-based [8,9,12,13,15,17,19]. Feature-based methods extract discriminative feature from face image either by hand-crafted descriptors [5,10,18] or feature learning [6,7,14,16], to describe the genetic traits on human face. Model-based methods, however, aim to learn an appropriate distance metric or classifier based on some statistical learning techniques. Among them, distance metric learning (DML) [20–23] has been a promising choice for learning the kin similarity metric on face [12,13,15,17,19]. Most DML-based kinship verification methods suffer from two limitations; on one hand, they aim to learn a Mahalanobis distance metric parameterized by a full matrix for each feature representation, making the training and testing computationally inefficient for high-dimensional kin data. On the other hand, they seek to learn the kinship similarity metric in batch learning mode, making the process less scalable in practical verification tasks with ever-growing amount of training data collected and stored in the kinship databases. To address these issues, we propose in this paper a scalable similarity learning (SSL) method for KVFI.

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Fig. 1. Some image examples (with kinship relation) from the KinFaceW-II dataset [12]. From top to bottom are father–son (F–S), father–daughter (F–D), mother–son (M–S), and mother–daughter (M–D) kin relations, respectively.

Different from existing kinship verification methods, our proposed SSL seeks to learn a diagonal bilinear similarity metric on the human face based on an online sparse learning strategy, which enjoys superiority in efficiency and scalability for KVFI with high-dimensional kin data. In practice, we have access to multiple views (feature representations) of face data, each of which can be individually used for kinship verification. Exploiting information from multiple views, we hope to find a fused similarity metric on face appearance that is more robust and accurate than the ones learned by using the individual views. As such, we further develop a multiview SSL method by optimal fusion of the diagonal similarity models from multiple feature representations in a coherent process, such that the interactions and correlations in multiview kin data can be leveraged to obtain the refined and high-level information. The contributions of this work are summarized as follows:

1) A scalable similarity learning method is proposed for training the kin similarity metric on the human face by introducing the truncated gradient to induce sparsity in online learning of the diagonal bilinear similarity function, making it computationally efficient and scalable for practical KVFI with high-dimensional kin data.
2) A multiview SSL algorithm is developed for effective fusion of kin similarity by an optimal combination of the diagonal bilinear similarity models from multiple feature representations in a coherent online process.
3) We empirically evaluate our SSL method against the state-of-the-art DML-based solutions to KVFI on two widely used kinship datasets, and the experimental results demonstrate that our method can achieve competitive or better verification performance, and enjoys superiority in computational efficiency and scalability.

The remainder of this paper is organized as follows. We briefly review the related work on kinship verification methods in Section 2. In Section 3, we first elaborate the scalable similarity learning method for KVFI, and then the multiview SSL algorithm is derived. Experiments and evaluations of our method are conducted in Section 4. Finally, we conclude the paper in Section 5.

2. Related work

We briefly review the work related to kinship verification in this section. The existing kinship verification methods can be roughly divided into two categories: feature-based [5–7,10,14,16,18] and model-based [8,9,12,13,15,17,19].

2.1. Feature-based methods

As a first attempt at KVFI, Fang et al. [5] proposed to extract various local features (*e.g.*, skin color, histogram of gradient, and others) from facial components to recover genetic traits on the human face. Guo and Wang [10] proposed to use the DAISY descriptors for matching of facial components with spatial Gaussian kernels. Zhou et al. [6] introduced a learning-based descriptor for representation and recognition of the kin faces. Yan et al. [14] proposed to construct a set of unlabeled face samples from the Labeled Face in the Wild (LFW) dataset as the reference set, and then introduced a prototype-based feature learning method for the verification problem. Recently, a deep learning method, the gated autoencoder [16], has been proposed to characterize the resemblance between the parent-child pairs. Other feature representations or learning methods for KVFI include Self Similarity Representation (SSR) [18], Gradient Orientation Pyramid (GGOP) [7], and facial dynamics [11].

2.2. Model-based methods

Recently, similarity metric learning [20–23,34] has been a popular solution to kin similarity measure on human faces [12,13,15,17,19]. In [12,13], Lu et al. introduced a neighborhood repulsed metric learning (NRML) method for KVFI. They approach this by learning a kin metric based on which the face examples with kin relation are pulled close and those without kin relation