



# Ensemble similarity learning for kinship verification from facial images in the wild



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## ABSTRACT

Kin relationship has been well investigated in psychology community over the past decades, while kin verification using facial images is relatively new and challenging problem in biometrics society. Recently, it has attracted substantial attention from biometrics society, mainly motivated by the relative characteristics that children generally resemble their parents more than other persons with respect to facial appearance. Unlike most previous supervised metric learning methods focusing on learning the Mahalanobis distance metric for kin verification, we propose in this paper a new Ensemble similarity learning (ESL) method for this challenging problem. We first introduce a sparse bilinear similarity function to model the relative characteristics encoded in kin data. The similarity function parameterized by a diagonal matrix enjoys the superiority in computational efficiency, making it more practical for real-world high-dimensional kinship verification applications. Then, ESL learns from kin dataset by generating an ensemble of similarity models with the aim of achieving strong generalization ability. Specifically, ESL works by best satisfying the constraints (typically triplet-based) derived from the class labels on each base similarity model, while maximizing the diversity among the base similarity models. Experiments results demonstrate that our method is superior to some state-of-the-art methods in terms of both verification rate and computational efficiency.

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## 1. Introduction

Soft biometrics often refer to human characteristics providing categorical information about people such as beard, age, gender, ethnicity, gait and gestures, etc. Different from the hard biometrics (e.g., face, fingerprint, and iris) that are generally unique and permanent, soft biometrics provide some vague information that is not necessarily distinctive. Such soft biometric traits are usually easier to capture and often do not require the cooperation from the subjects. They can be used to improve the verification performance of biometric recognition. In soft biometrics, kinship verification using facial images is a relatively new and challenging problem [1], although kin relationship has been well studied in psychology society over the past decades. More recently, it has attracted substantial attention from biometrics society, mainly motivated by the observation that children generally resemble their parents more than other persons with respect to facial appearance, due to the genetic overlapping. Recent evidence from psychology has demonstrated that face appearance is a reliable and

key cue to measure the genetic similarity between children and their parents [2–7]. In practice, there exist some important and potential applications of kin verification using face images, ranging from missing children search to social media analysis [8,9]. Fig. 1 presents some image examples (with four kin relations) from the KinFaceW dataset [10].

Over the past a few years, some seminal works on kin verification from facial images [1,8,9,11–18] have been proposed. While some inspiring results have been obtained, kinship verification still remains open, since face images are often captured in wild conditions, and varying poses, expressions, and aging in such scenarios make the verification problem extreme challenging [9]. The appearance gap in a kinship verification system is much larger than that in a face recognition system, since the test input for the former are typically given by two facial images with different sex and different age. Furthermore, the difference of face images with kin relationship is sometimes large and even higher than the difference of face images without kin relation. As a result, kin relationship among family images is quite difficult to recover in original distance (similarity) metric space, and more robust similarity measure is desirable for practical kin verification in the wild.

In ensemble learning, multiple weak (base) learners are trained on the labeled dataset and then combined to achieve strong

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Fig. 1. Some image examples (with kin relation) from the KinFaceW-I dataset [10]. 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.

prediction or generalization performance [19, 20]. It is well-known that the generalization ability of an ensemble is related to average generalization ability of the weak learners and the diversity among the weak learners. Motivated by this, we formulate the similarity learning in the ensemble learning framework to address the kinship verification problem. The philosophy of our ensemble similarity learning method is that, the measure ability of a similarity ensemble is related to the average measure ability of the weak similarity models and the diversity among the weak similarity models, the higher the average measure accuracy of the weak similarity models and the higher the diversity among the weak similarity models, the better the prediction ability of the similarity ensemble.

In this paper, we focus on learning a genetic similarity measure between child-parent pairs in ensemble learning framework for kin verification via facial images in the wild. The key idea of our method is to learn an ensemble of multiple similarity functions with the goal of achieving strong generalization ability, such that the intrinsic similarity between the parent-child pairs can be well discovered in the *fused* measure space. To this end,

- (1) We introduce a sparse bilinear similarity function to model the relative characteristics that children often resemble their parents more than other persons with respect to facial appearance due to the genetic overlapping. This sparsity-inducing similarity model is able to achieve comparable accuracy to some state-of-the-art solutions, while enjoys the superiority in computational efficiency, making it more practical for real-world high-dimensional kin verification applications.
- (2) We propose an ensemble similarity learning (ESL) method for kinship verification. ESL learns from kin data by generating an ensemble of similarity functions with the goal of achieving strong generalization ability. Specifically, ESL best satisfies the constraints (typically triplet-based) derived from the class

labels on each base (weak) similarity function, while maximizing the diversity among the ensemble similarity functions. Conventional multi-metrics learning methods [9, 21] are focused on learning multiple distance metrics from multi-view data. By contrast, our proposed ESL works by learning an ensemble of similarity models from the single feature space, while enforcing the diversity on the fused measure space to enhance the robustness of the similarity model to large intra-class variance of real-world kin data.

- (3) We conduct extensive experiments on the KinFaceW-I and KinFaceW-II datasets [9] by comparing the proposed ESL algorithm with the state-of-the-art methods for kinship verification in the *image-unrestricted* setting. Experimental results demonstrated that our method is superior to some state-of-the-art solutions in terms of verification accuracy as well as computational efficiency.

The remainder of this paper is organized as follows. In Section 2 we review the related work on kinship verification methods. In Section 3, we first introduce a sparse similarity model for the relative characteristics of kinship problem, and then elaborate the ensemble similarity learning method for kinship verification problem. Experiments and evaluations on verification performance are conducted in Section 4. Finally, we conclude this paper in Section 5.

## 2. Related work

The goal of kinship verification through biometrics is to determine whether a given pair of face images has kin relation. Recent evidence in psychology society shows that face appearance is a useful cue for measurement of the genetic similarity between children and their parents, and human is able to recognize kin relationship based on face images [3–6]. Motivated by this key observation, efforts on kin verification via face images have recently been made by researchers from biometrics society [1, 8, 9, 11–18, 21–23].

As an early attempt at this challenging task, Fang et al. [1] use various local facial features extracted from facial components to recover distinguishable cues from facial appearance. These local features include skin color, histogram of gradient, and facial structure information. In [13], Guo and Wang propose to use the DAISY descriptors for facial components (e.g., eyes, mouth and nose) matching with spatial Gaussian kernels. In [11], Zhou et al. propose a Spatial Pyramid LEarning-based (SPLE) descriptor for representation and recognition of the kinship faces. Yan et al. [23] propose a prototype-based discriminative feature learning (PDFL) method for kin verification. They construct a set of face samples with unlabeled kinship relation from the labeled face in the wild dataset as the reference set, and learn discriminative mid-level features to better characterize the kin relation of face images. In [24], a gated autoencoder is trained to characterize the resemblance between a parent-child pair of faces, by minimizing the reconstruction error based on a set of randomly sampled local face patches. Other feature representations for kinship verification include self similarity representation (SSR) [17], gradient orientation pyramid (GGOP) [14], semantic-related attributes [22], and facial dynamics and spatio-temporal appearance over smile expression [15].

More recently, metric learning [25–29] has been a promising choice for measure of the kin similarity [9, 16, 21, 30]. In [9], Lu et al. propose a neighborhood repulsed metric learning (NRML) method for kinship verification. They achieve this aim by learning a distance metric under which the examples with kin relation are pulled close and those without kin relation are pushed away. In [9, 21] and [30], the authors show that exploiting complementary information from multi-view feature space for metric learning is useful to further boost the verification performance. In order to reduce the similarity gap of kin faces, Xia et al. [8, 18] propose to use intermediate young parent facial

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