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A composite spatio-temporal modeling approach for age invariant face recognition

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ABSTRACT

In this research we propose a novel method of face recognition based on texture and shape information. Age invariant face recognition enables matching of an image obtained at a given point in time against an image of the same individual obtained at an earlier point in time and thus has important applications, notably in law enforcement. We investigate various types of models built on different levels of data granularity. At the global level a model is built on training data that encompasses the entire set of available individuals, whereas at the local level, data from homogeneous sub-populations is used and finally at the individual level a personalized model is built for each individual. We narrow down the search space by dividing the whole database into subspaces for improving recognition time. We use a two-phased process for age invariant face recognition. In the first phase we identify the correct subspace by using a probabilistic method, and in the second phase we find the probe image within that subspace. Finally, we use a decision tree approach to combine models built from shape and texture features. Our empirical results show that the local and personalized models perform best when rated on both Rank-1 accuracy and recognition time.

1. Introduction

Face image recognition is an important and significant part of the domain of biometric research (Cootes, Edwards, & Taylor, 1999; Gong, Li, Tao, Liu, & Li, 2015; Jain, Nandakumar, & Ross, 2016; Li, Park, & Jain, 2011; Park, Tong, & Jain, 2010; Ramanathan & Chellappa, 2006). It has important applications in real life in the fields of missing children identification, passport verification, security, animation and business intelligence. For example, in case of law enforcement, an image of a suspect is available and we need to find out whether the image of the same person exists and can be obtained from our crime database or not. If the suspect does actually appear in the crime database at a previous age then a match should be made and information on the last known address and other associated information of the suspect can be retrieved from the crime database.

Inspite of extensive research in face recognition (Gong, Li, Lin, Liu, & Tang, 2013; Gong et al., 2015; Li et al., 2011; Ramanathan & Chellappa, 2006) much ground has not been covered in the field of age invariant face recognition (Gong et al., 2013; Gong et al., 2015; Li et al., 2011; Park et al., 2010). Face recognition has two main areas of research namely, face verification and face identification. There are two types of approaches used in age invariant face recognition, generative and non generative. Generative approaches assume prior knowledge of human age, given an image. On the other hand, non-generative approaches concentrate on finding discriminative features of the face and the changes therein throughout the face aging lifespan. From another perspective we can identify three main directions of research related to face recognition across age: viz, age invariant face recognition, age simulation and age estimation. Most research has concentrated on age estimation and age simulation. Research into age invariant face recognition is still at a nascent stage.

In this paper we will concentrate on age invariant face recognition across different ages with special emphasis on the identification problem (see illustration in Fig. 1).

Aging is a complex problem because at different age points different types of changes occur in the human face. From childhood to teenage the changes are mostly related to craniofacial growth. At maturity the changes are mostly related to the skin color changes and texture effects, with facial skin starting to become slack and less smooth. So aging is a mixture of all of these components. Moreover, aging is a slow, irreversible, and a process that is unique to every human being. Many factors affect the aging process. For example every person has different genes, blood group, life style and belongs to a particular ethnic group. In order to resolve all

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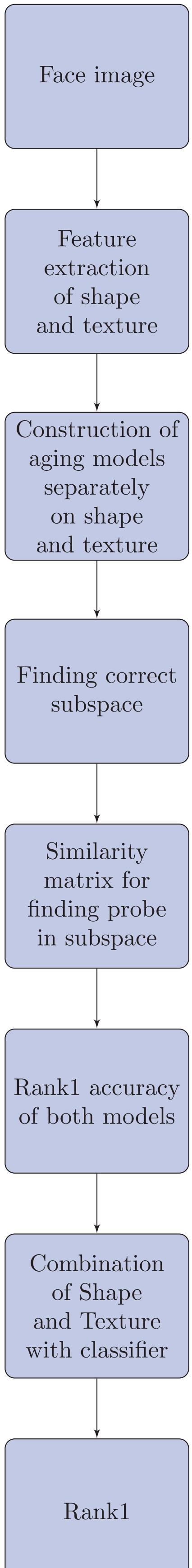

Fig. 1. Proposed methodology.

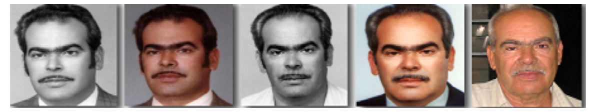

Fig. 2. Same individual at different ages from FG-NET (FG-NET, 2002).

Fig. 3. Same individual at different ages from MORPH (Ricanek Jr & Tesafaye, 2006).

these issues we need to deal with shape and texture features separately and finally combine them to exploit the natural synergy between these two types of features.Figs. 2 and 3 show images of two persons at different ages.

There are five major challenges which affect the performance of face recognition systems: pose, illumination, expression, occlusion and aging. It has been observed in past research that for resolving one challenge we need to compromise on others (Abdullah et al., 2014; Geng, Zhou, & Smith-Miles, 2007; Pujol & García, 2012) Thus, there is a need to find a solution that compromises on the minimum number of factors or challenges.

We use a novel approach in this paper making a two pronged attack on these challenges by using both shape and texture features. We build an Anthropometric model which is based on geometrical ratios and distances of a fixed number of fiducial landmarks. Such a model is not affected by occlusions such as moustaches or spectacles because landmarks do not alter their position. Likewise, facial expression and illumination also do not significantly alter the position of landmarks. However, different poses could create problems. To mitigate this problem, we take an average frontal image and warp all our images to that image through Procrustes analysis (Cootes et al., 1999). That leaves the aging aspect which is our main area of research and our study fully focuses on that area. We use edges on the face texture to extract wrinkles information and together with the Anthropometric features we build and analyze the aging process. We have used these same features in our previous studies (Alvi & Pears, 2015a; 2015b) as well. The contributions we make in this research are:

- We partition an image gallery into sub galleries by time segment before applying a probabilistic Bayesian method to identify the segment containing the desired (target image). Our empirical results show that such partitioning helps to improve recognition accuracy.
- We use a local modeling approach whereby we partition the global population of images into homogeneous sub-populations of clusters and build localized models on each of the clusters. This partitioning is orthogonal to the time based partitioning mentioned above.
- We combine shape and texture models in order to exploit any synergy that exists between them. In certain cases, both types of models point to the same image which happens also to be the right one. In such cases having two types of models enhances the robustness of the matching process as agreement exists. However in certain other cases, each model could identify different images. Conflict resolution is then necessary and we make use of a decision tree classifier for resolving such conflicts. Our choice of the decision tree classifier was based on the fact that it had the highest conflict resolution success rate out of the classifiers that we experimented with, which included

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