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INTRODUCTION TO HUMAN AGE ESTIMATION USING FACE IMAGES

Petra GRD

ABSTRACT

Age estimation is one of the tasks of facial image classification. It can be defined as determination of a person's age or age group from facial images. This paper gives an overview of recent research in facial age estimation. Along with an overview of previous research on this topic, descriptions of basic age estimation models are given: anthropometric model, active appearance model, aging pattern subspace and age manifold.

KEY WORDS

biometrics, face recognition, facial aging, age estimation, craniofacial morphology, aging pattern subspace, age manifold, active appearance

INTRODUCTION

Age estimation is an important task in facial image classification. For research purposes, definitions of basic terms are given. Age estimation in this study is defined as age of a person based on his or hers biometric features, precisely on the basis of two-dimensional facial images [1]. Facial characteristic points can be defined as a standard reference points on human face used by scientists in order to recognize a person's face, or in this case, to estimate the age of a person [2]. Morphology by itself is a study of form [3]. Therefore, the craniofacial morphology is a study of shape of the face and skull. Changes in texture of face are defined as changes in face associated with skin and muscle elasticity [4]. The aging process affects structure and appearance of a person in many ways. The changes that occur are related to craniofacial morphology and face texture. Certain features of craniofacial morphology appear only in people of certain age and change during the aging process. Changes in skin texture usually occur in adulthood.

There have been many research on craniofacial morphology of individuals from different aspects. One of these studies is the one conducted by Patterson et al. [5]. They propose using aging function based on AAM (Active Appearance Model), which is based on the use of PCA (Principal Component Analysis) method. In 1994. Kwon and Lobo [6] proposed theory and practical calculation for age classification of face images. Their calculations are based on craniofacial morphology and wrinkle analysis. Combining the analysis of the face ratios and

Petra Grd - Faculty of organization and informatics, Pavlinska 2, Varaždin, petra.grd@foi.hr

wrinkle analysis, faces are classified in three different classes. Geng et al. [7] presented the AGES (Aging Pattern Subspace) method for age estimation. The basic idea is to model the aging pattern, which is defined as a sequence of images sorted in time order, by constructing a representative subspace. The proper aging pattern for a previously unseen face is determined by the projection in the subspace that can reconstruct the face image with minimum error, while the position of the face image in that aging pattern indicates age.

Besides these, many other studies concerning age estimation have been conducted [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19],[20], [21], [22], [23].

There are some problems in age estimation, and one of those problems is ethics of age estimation, especially in age estimation of children. Existing methods, such as skeletal and dental age estimation are invasive and according to European Council Directive 97 ⁄ 43 ⁄ Euratom people have the legal right to object a medical age estimation [30]. In a study of alternative reception arrangements at the port of Dover in England, unaccompanied children were placed under the care of the Social Service Department for a period of 7 days, during which the age assessment was carried out. In subsequent interviews, the children expressed annoyance of having participated in a process that they did not understand and which they experienced as hostile [31].

AGE ESTIMATION

Age estimation can be defined as determination of a person's age or age group. Person's age can be determined in many ways, but this research is concerned with age estimation based on two-dimensional images of human subjects.

According to Geng et al. [4], there are several types of age:

- Chronological age is defined as the number of years a person has lived
- Appearance is the information about age, defined by person's appearance
- Perceived age is defined by other people who define it on the basis of a person's appearance
- Estimated age is the age defined by computer based on persons appearance

Appearance age is usually very close to the actual or chronological age. The objective of age estimation is that estimated age is as close to appearance age as possible.

FACIAL CHANGES DURING GROWTH AND AGING

Geng et al. [4] in their work on the automated age estimation recognized two stages of facial aging. The first phase is the early years, defined as the years from birth to adulthood. At this stage, most of the changes are caused by changes in craniofacial growth:

- Chin becomes more prominent
- Cheeks are spread over a larger area
- Characteristics of the face increase and cover the interstices
- Forehead falls back, reduces the free space on the surface of the skull

In addition to changes caused by craniofacial growth, minor changes in the skin occur [4]:

- Facial hair become denser and change color
- Skin color changes

The second phase of the aging face, recognized by Geng et al. [4] is during adulthood. Adulthood is defined as the time from the end of growth to old age. The main changes in this stage are changes in skin texture. Skin becomes thinner, darker, less elastic and more leathery. Also, wrinkles, under chin, sagging cheeks and lowered bags under the eyes appear. But there is also some small craniofacial growth at this stage, mainly changes in the shape of the face, but most of the craniofacial growth occurs at an early age of the individual.

FACIAL REPRESENTATION MODELS

There are many different models for facial representation. Models recognized in [4], [24], [23] are:

- Anthropometric Model
- Active Appearance Model
- Aging Pattern Subspace
- Age Manifold.

Anthropometric model

Facial Anthropometry is the science of measuring the size and proportions of the human face [25].

The main idea of this model is to consult research related to craniofacial growth and development. Craniofacial research theory uses a mathematical model for description of a person's head from birth to adulthood: $\Theta' = \Theta$, $R' = R\,(1 + k\,(1-\cos\Theta))$ where Θ is the angle formed by the vertical axis, R is the radius of the circle, k is a parameter which increases with time, and (R', Θ') circuit growth over time [26]. Farkas gave an overview of facial anthropometry. He defined facial anthropometric as measures taken from 57 characteristic points of the face taken over years [27]. For age estimation, distances and ratios between characteristic points are commonly used, instead of using a mathematical model, because it is difficult to measure face profile on the two-dimensional face images [23].

Computations in this model are based on the craniofacial development theory. Changes in the appearance of face caused by the growth and texture samples are sufficient to categorize faces in several age groups. This model is suitable for a rough age estimation, but not for detailed classification [15].

Anthropometric model is based on rations of the human face, as shown in Figure 1.

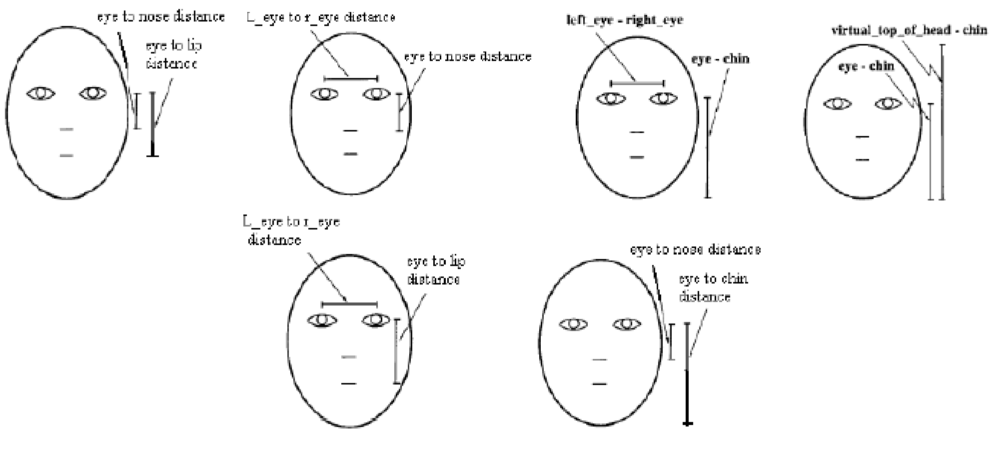

Fig. 1 *Ratios on human face [11]*

This model is useful for the classification of people in minors and adults, but it cannot distinguish between adults of different age [4], for example, young adults and seniors. This is the main reason why Kwon and Lobo [6] used wrinkle analysis to distinguish between young adults and elderly.

Anthropometric model is useful for younger people, but not for adults. In practice, it can only be used for en face images for measuring facial geometry, because the distances and ratios are calculated from two-dimensional images of individuals that are sensitive to the positions [23]. This model takes into account only geometry of face, without information about the texture.

Active appearance model

This model was proposed in 1998. by Cootes et al. [39]. Using facial images, statistical shape model and intensity model are learned separately. In 2002 The AAM has been expanded to facial aging [28] suggesting an aging function defined by age = f (b), to explain the variation in years. *Age* is the age of a person in the picture, *b* is a vector containing 50 parameters learned from AAM, and *f* is an aging function. The function defines the relationship between person's age and facial description parameters [23]. There are different forms of an aging function. Some examples of such functions are: quadratic aging function, linear aging function, cubic aging function and others.

Unlike anthropometric model, AAM is not oriented only to younger people, but deals with assessment of the age of people of all ages. It works in a way that takes into consideration not only the geometry of human face, but its texture also. In this way the age of a person can be estimated more accurately [23].

Aging pattern subspace

Instead of using every face image separately aging pattern subspace model uses a sequence of facial aging images to model the aging process. This model was developed by Geng et al. [4] and named AGES (AGing pattErn Subspace). Aging pattern is defined as a sequence of facial image of a person, sorted by time.

AGES works in two steps. The first step is a learning step, the second step is the age estimation step [23]. In the first step, PCA is used to obtain the subspace representation. The difference from the standard PCA approach is that there are probably no images for each year for each aging pattern. So EM (Expectation-Maximization) is used as a method of iterative learning to minimize error in reconstruction. Error while reconstruction is defined as the difference between the available images of the face and the face reconstructed images [23]. In the second step, the test face image needs to find a pattern of aging that suits that image, and the exact position of the year in the sample. Position year returned is the estimated age of a person in the test image [23].

To cope with incomplete data, due to difficulties in data collection, the aging pattern subspace models the sequence of a person's aging face images by learning subspaces. Age of the person being tested is determined by the projection in the subspace that can best reconstruct the face image [15].

Methods based on aging functions view age estimation as a classification problem: face images are data, and the goal is the age of a person in the picture. According to [4] aging pattern is a sequence of images sorted by age.

The emphasis of this model is the use of facial images of a person at different ages to define the aging pattern.

Age manifold

Instead of learning the specific aging pattern for each person, it is possible to learn the common pattern of aging for more than one person at different ages. For each age, more than one facial image is used for age representation. Each person can have several face images in one age or in an age range [23]. Therefore, this model is more flexible than AGES model, and it is much easier to collect a larger number of samples (facial images) and create a larger database.

This model uses a manifold embedding technique for learning a low-dimensional aging trend for many facial images of the same age. The only requirement of this model is that the sample size for learning is large enough so that embedded manifold can be taught with statistical sufficiency [29].

COMPARISON OF ALGORITHMS

There are a large number of algorithms and some of them have been described in the introduction of this paper. To compare these algorithms, Mean Absolute Error (MAE) is used in most of these papers. MAE is defined as average absolute error between estimated and chronological age [32]. The lowest the MAE the more accurate the algorithm is. Most commonly used database also used in this comparison is FG-NET database. Algorithms by MAE can be seen in Table 1 [33].

ALGORITHMS BY MAE Table 1

Algorithm	MAE
K-nearest neighbor	8,24
Support Vector Machines	7,25
Local feature of face image and regression	6,85
Aging Pattern Subspace	6,77
Nonlinear Aging Pattern Subspace	6,18
Ranking with uncertain labels	5,33
Metric learning and Gaussian Process Regression	5,08
Manifold learning and locally adjusted robust regression	5,07
Regression Patch Kernel	4,95
Active Appearance Model	4,37
Enhanced bio-inspired features	3,17

CONCLUSION

Age estimation of humans using their facial images is by itself insufficiently researched, but it is widely applicable and has great potential: determining the age of immigrants or asylum seekers in situations where there are no documents proving the person's age, for places on the Internet where entrance is permitted only to persons older than 18 years, in order to improve the face recognition systems (most of the systems are sensitive to changes during aging), searching for missing persons over many years, the human-computer interaction based on age, for the purpose of predicting persons aging, and in the fight against pedophilia (removing images of minors from various portals or personal computers). The above are just some of the possible uses of a person's age estimation, and with further development of new technologies, there will be more.

This paper gives an overview of the field of facial age estimation. Along with an overview of previous research on this topic, description of basic age estimation models is given: anthropometric model, active appearance model, aging pattern subspace and age manifold. Future research will regard age estimation from a classification point of view. First step will be classification of individuals in a small number of classes based on their facial images, and later, an exact age classification will be researched.

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