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Kinship-Guided Age Progression

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ABSTRACT

Age progression is defined as aesthetically re-rendering an aging face with identity preservation and high credibility at any future age for an input face. There are two main challenges in age progression: (1) age progression of a specific individual is stochastic and non-deterministic, though there exist some general changes and resemblances in this process for a relatively large population; (2) there may not be apparent identity information for people at the tender age. In this work, we present an efficient and effective Kinship-Guided Age Progression (KinGAP) approach for an individual, which can automatically generate personalized aging images by leveraging kinship, or more specifically, with guidance of the senior kinship face. The proposed approach mainly consists of three aging modules, which are designed to preserve individual aging characteristics, capture human aging tendency, and guide aging direction, respectively. Extensive experimental results and user study analysis on our constructed age-kinship face dataset validate the superiority of our approach.

1. Introduction

Human age is one of the crucial face biological attributes. Human facial aging is generally an inevitable and irreversible process, even though some medicines and the advanced cosmetic surgery may slightly reverse minor aging effects [1]. Generally, there are some general changes and resemblances in human facial aging process. We can always describe some global biological characteristics by statistics, such as craniofacial growth (shape change) from birth to adulthood, more protrusive chin as aging, smaller eyes as aging, growing wrinkle as aging, more dense mustache as mature, and skin aging from adulthood to agedness [1].

In the last decade, many research efforts have been devoted to human age related research, such as age progression [1–9], age estimation [10–14], face aging database construction [15–17], face aging evaluation [18] and age-variant facial analysis [15,19–22]. Age progression, also called age synthesis [1] or face aging [4], is attracting increasing interest in new emerging applications, e.g., extremely age-variant face analysis, authentication systems, finding lost children, and entertainment. For a given face photo, some representative approaches focusing on age progression [4,5,18] seek to solve face aging problems through harnessing the global aging characteristics and have achieved impressive results.

Based on the different proposals for age progression, we categorize the existing age progression methods into three sub-settings: *physical age progression*, *model-based age progression* and *prototyping age progression*. These three methods will be introduced in the following section in detail. *Prototyping age progression* utilizes the average face in different ages (ranges) to capture the human aging characteristics, and then adds the face aging difference between the current age and target age to the input face in the current age. Compared to *physical age progression*, the advantage of *prototyping age progression* is more easy for implementing. Compared to *model-based age progression*, the advantage of *prototyping age progression* does not need the sufficient intra-person long-term aging face images as the training data. Therefore, we consider the *prototyping age progression* as the basic proposal in this paper. Since *prototyping age progression* often employs the average faces in different age groups as the aging information, it only can capture the human aging characteristics, but lost some personalized aging characteristics for different individual faces, e.g., mole, birthmark, and skin color, which are also related to the identity information. Thus, human aging characteristics and individual aging characteristics for an input individual face should be simultaneously considered into the age progression.

Human babies with age 0–4 have similar appearances, and will gradually and slowly show the identity information on the face from birth to puberty. After arriving at puberty, the contour and texture of a face are greatly changing, which brings more complete identity information. In other words, it may be difficult for the

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existing age progression approaches to well capture the *personal identity* of an aging face due to the possibly unapparent identity information in the input photos during the infancy and childhood. For a specific individual, the aging speed may be different from others, due to genetic difference, various lifestyle, etc. Moreover, the aging progression of an individual is *stochastic* and *non-deterministic* in the time dimension. Like Brownian motion, the number of possible aging sub-spaces increases along the direction of the time axis [4]. However, there has been little literature considering the diversity of individual aging progression, besides the global aging characteristics. Therefore, the aging direction is an important factor for age progression.

Can senior family members provide a positive prior to guide the stochastic and non-deterministic age progression, as well as enhance personal identity? One key inspiration comes from the following observation: people have the capability to recognize kinship based on apparent features of two faces, even two unfamiliar faces. Moreover, a recent series of studies related to kinship verification [23–25] have further validated by the computational models that two persons with kinship are biologically related. Therefore, it is concluded that: (1) to preserve the kinship, the aging face of a child should be consistent with his/her parent in terms of aging mechanism, namely "like father, like son"; (2) as a prior, kinship information can guide the direction of age progression.[1]

In this paper, the goal is to improve the performance of age progression by leveraging available kinship information, especially for the identity enhancing and genetic invariance. Considering both the global aging direction and the individual-specific aging diversity, we present an efficient and effective Kinship-Guided Age Progression (KinGAP) approach to automatically generate convincing aging images at any future age, which not only shows the identity information, but also reflects authentic aging outcome. This approach belonging to *prototyping age progression* mainly contains three aging modules: individual-aging residual blending, average-aging tracking, and kinship-aging morphing, which are designed for the individual aging characteristics, human aging tendency, and aging direction, respectively. The individual aging characteristics can capture the personalized aging characteristics, e.g., mole and skin color; the human aging tendency can capture the human aging characteristics, namely the common aging characteristics; while the aging direction can guide the aging direction. These three modules are introduced in Section 4.1 in detail.

Fig. 1 shows two example results by our approach. Take the son and the father from the Beckham family in the top row as an example. The first image of the child with age 14 is the input, while the third image is his father with age 38. Firstly, we observe that the aging face (the second image) is close to that of the actual age 38, and thus is *natural* and authentic. Secondly, the aging face not only preserves his *identity* information from the input, but also looks like his father with age 38, which indicates that the deterministic aging face inherits the *genes* from his father. Thirdly, the aging image is *aesthetic* and attractive from the view of color contrast and saturation. *Overall*, the aging result is appealing. Therefore, these two aging images are satisfactory from the *Aesthetics*, *Identity*, *Nature*, *Gene* and *Overall* (AINGO) perspectives, respectively.

The rest of the paper is organized as follows. In Section 2, we briefly introduce the previous works. Then, the overview of our approach is described in Section 3, followed by the technical details in Section 4. The experimental evaluations and analysis are shown later in Section 5 and finally we conclude the paper in Section 6.

[1] Here, some uncontrollable factors (e.g., lifestyle, living environment, disease and cosmetic) also influence human aging regularities to different degrees, but they are beyond the scope of this paper.

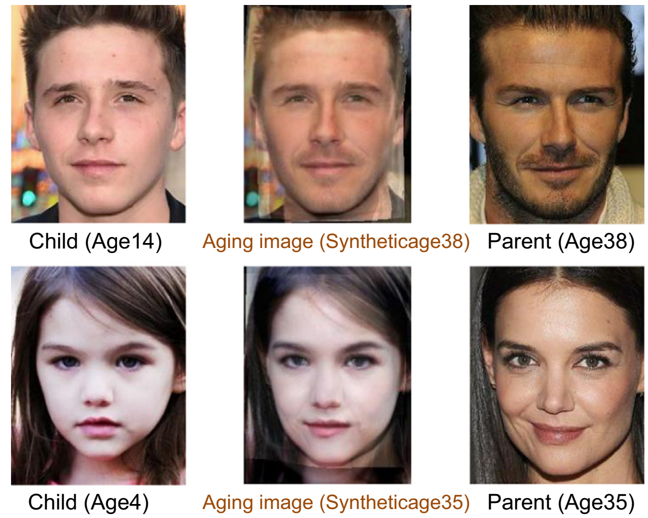

Fig. 1. Aging images by our approach. Given an input image of a child (i.e., the first column) with his/her parent prior (i.e., the third column), our approach can automatically generate his/her aging image (i.e., the second column). Age in bracket behind "Aging image" denotes the synthetic age, while age in bracket behind "Child" and "Parent" represents actual age.

2. Previous works

Among the early studies, Burt and Perrett [26] focused on the age-related visual cues of human faces and gave some insights into the task of age progression for adults. In recent years, age progression has been comprehensively reviewed and discussed in some literature [1–3]. Based on different technical proposals, we categorize age progression approaches into three sub-settings: *physical age progression*, *model-based age progression* and *prototyping age progression*.

2.1. Physical age progression

Physical age progression means simulating the aging face by employing perceptions of biological characteristics. For the changing of muscles as aging, Ramanathan and Chellappa [27] proposed a shape transformation model to implicitly account for the physical properties and geometric orientations of the individual facial muscles; Berg and Justo [28] employed the highly realistic 3D head model in comparison with the youth age face of the same person to present a prototype of aging for a specific region of one's face. Moreover, [29,30] presented the wrinkle model on human skin to simulate the skin aging of an individual person. Physical age progression is often complex and computationally expensive because of subtle facial structure and complex face aging mechanisms.

2.2. Model-based age progression

Model-based age progression models facial parameters for each actual age label or group on the shape or texture synthesis by an explicit or implicit function. This case assumes each face image to be a high-dimensional point in the age space. Generally, considering shape and texture synthesis simultaneously is the most popular way [31], due to the sharp changes during the child's growth as well as the remarkable texture and subtle shape changes during the adult's aging. There have been quite a quantity of

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