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2D Generative Faces for Evolutionary Social Simulation

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Premise

The simulation of crowds constitutes a useful technique for improving the appearance of CG animations in films and computer games. Since it would look weird if the faces of all the simulated people look exactly the same, there is a need to develop generative algorithms that can automatically generate a wide variety of individual faces. Such algorithms are not only useful for the purpose of interacting with simulated characters such as in computer games but also for observing and understanding activities and events in social simulations.

In our previous work about a simulated evolutionary human society [1], each person was drawn as a simple two dimensional polygon with two colors. The shape of the polygon represents the sex of the person and the colors form part of a system of hereditary traits for appearance and aesthetic preferences. In this revised version of the social simulation, the visualization renders each person as a simple face. Similarly to the previous simulation, each person's face is drawn in such a way that a human observer can easily deduce the underlaying hereditary traits coded within the genome of the corresponding person.

The following sections describe the mapping between genetic information and rendering parameters, efficiency of rendering process, effects of visualization, and alternative drawings not by polygons but pixel-based images.

1. Parametric face shapes

In a real living organism, the physical appearance emerges through a complex morphological process of growth in which the underlaying genetic code only plays an indirect role. In our simulation, we omit this complicated process and employ a direct mapping between the genetic code and the drawing parameters of the face. While the number of parameters for drawing a visual representation of a human face is potentially enormous, our simulation employs a highly simplified visualization method that requires only five genetically encoded scalar values for drawing a face. Four of these parameters are mapped to the deformation of the face shape. The left-hand side of figure 1 shows the variation of adult male faces on the concentration and spread along the vertical and horizontal axes. A face at the center in this figure is by the neutral values of these parameters, of which elements are represented as a polygon constructed with a number of vertices. In order to realize the deformation, the following function f is applied to the original coordinate x and y to reposition them.

$$f(x) = \frac{\alpha x}{1 + (\alpha - 1)|x|}, \quad \alpha = \beta^g \ (g \in [-1,\ 1],\ \beta = 2) \tag{1}$$

where the origin of the coordinate system is assumed to be at the center, the coordinate range of drawing area is [–1, 1] for each axis, and g is the parameter. When g is –1, it is mostly spread. When g is 1, it is mostly concentrated. β is a coefficient to adjust the maximum deformation rate in the range of [1, ∞].

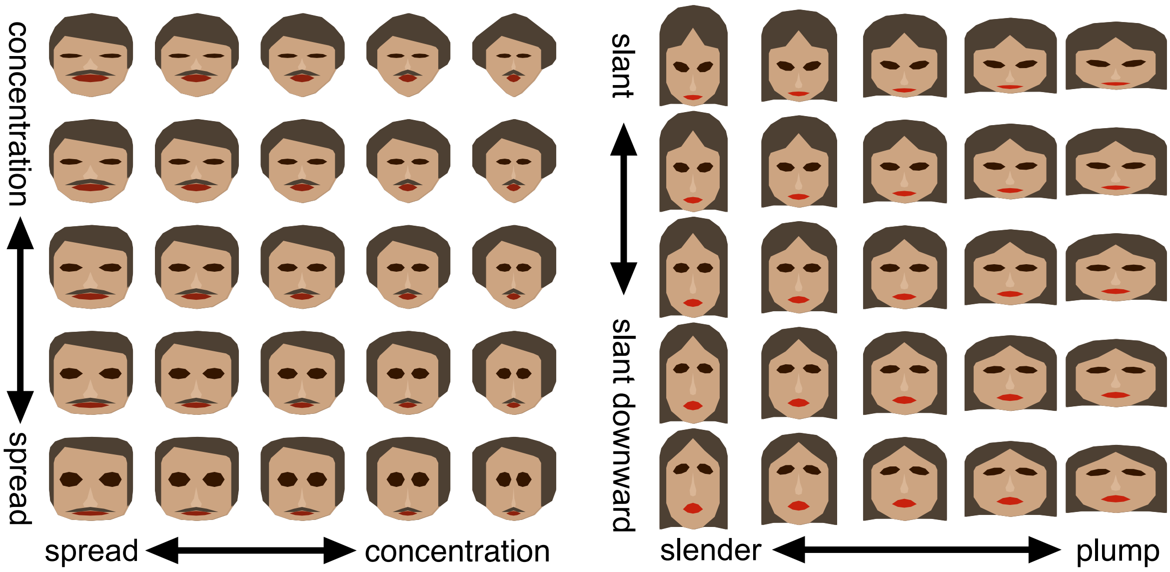

Fig 1. Left: Variation of male adult faces in vertical and horizontal concentration / spread. Right: Variation of female adult faces in plumpness and slant.

The right-hand side of figure 1 shows the variation of adult female faces on the aspect ratio for plumpness and vertical shift of the center for slant eyes. The former deformation is realized by simple linear offset for each coordinate using the following equations.

$$\Delta x = \eta k, \quad \Delta y = -\eta k, \quad (k \in [-1,1], \eta = 0.2) \tag{2}$$

where k is the parameter value. When k is –1, it is mostly slender. When k is 1, it is mostly plump. η is a coefficient to adjust the maximum deformation rate in the range of [0, 1]. For the latter deformation, the vertical coordinate y is shifted by the following value.

$$\Delta y = \gamma h \max(0, 1 - (x^2 + y^2)), \quad (h \in [-1,1], \gamma = 0.25) \tag{3}$$

where h is the parameter value. When h is –1, it is mostly slanted downward. When h is 1, it is mostly slanted. γ is a coefficient to adjust the maximum deformation rate in the range of [0, 1].

The fifth parameter affects the tanning of the skin color. The age of the simulated people also affects the shape and color of their faces. The position of the eyes and the top vertex of the nose are lower during childhood. The left and right edges of a face shift lower with increasing age. The color of the hair gradually becomes gray and finally white once a simulated person reaches a senior age. To make a clearer visual difference between sexes, we added a mustache to an adult male face older than 16 years. Figure 2 shows a variation of male faces in aging and tanning.

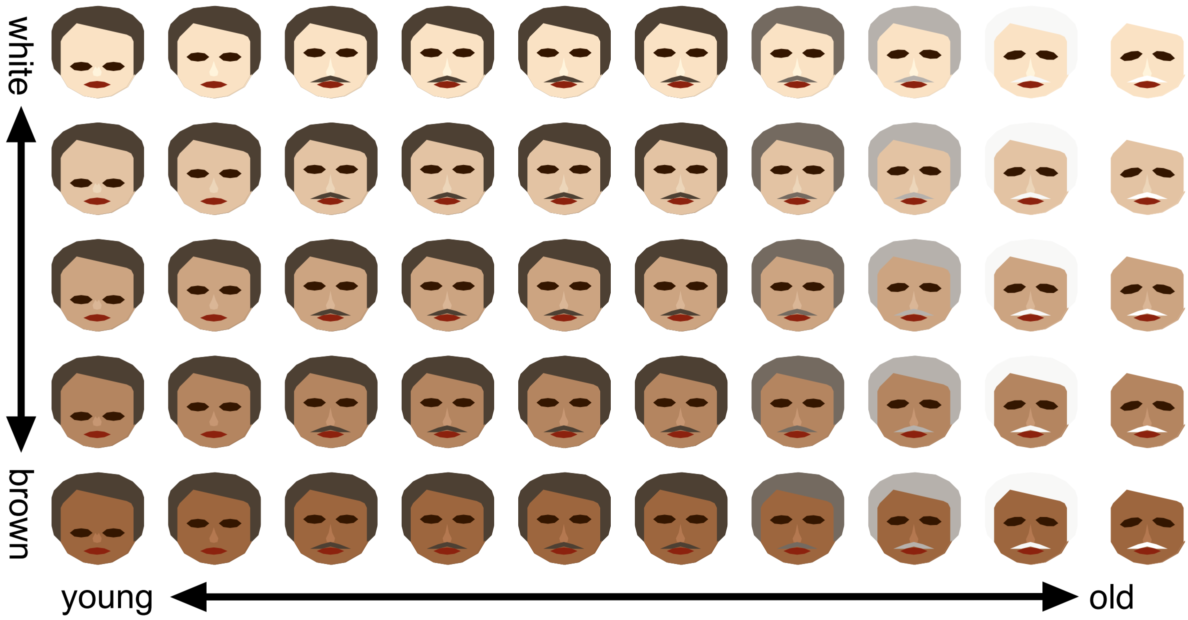

Fig 2. Variation of male faces in aging and tanning.

2. Rendering efficiency

The computational cost for rendering these faces is sufficiently low on the personal computer that is equipped with a recent graphic processing unit to allow the display of more than six thousands agents during each simulation step while preserving a smooth frame rate. However, it is also better to reduce the computation cost for drawing to achieve more efficiency for several reasons, for example, smooth animation by a low cost machine, reduction of energy consumption, and so on. One of the effective methods for this point is to reduce the number of vertices for each element in a face when the size is small enough. We prepared alternative shape data of which number of vertices is almost half of the original one. The original shape contains 146 vertices for a male face and 150 vertices for a female face. The number of vertices were reduced into 78 and 74 for each. The differences of the numbers between the sexes come from mustache of male and the difference in the hair shapes. In case the population consists of 6,000 agents with the same number of males and females, the total number of vertices is 146 × 3,000 + 150 × 3,000 = 888,000. As described in [1], the system has a functionality to display the 2D animation in arbitrary zooming scale. It is effective to use the reduced version when the view is zoomed out and the normal version when it is zoomed in. Figure 3 illustrates the differences between a normal one and a reduced one for each male and female.

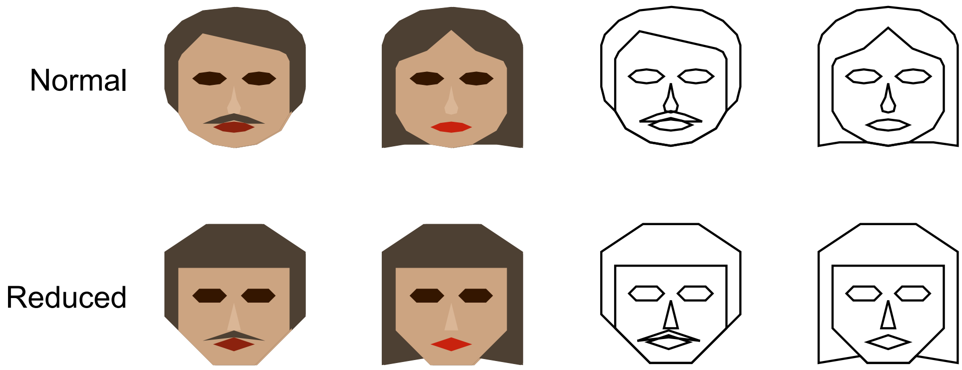

Fig 3. Normal and reduced shapes of male and female faces.

3. Effects of visualization

As has already been revealed by our previous work, the separation of appearances between different sexes is promoted through an evolutionary process that exhibits a selection pressure based on the reproductive advantage of heterosexual couples. This phenomenon becomes apparent in the simulation when observing the differences between facial characteristics of men and women drawn on the screen, even if these characteristics don't appear particularly natural when compared to real humans. The visualization also reveals a racial separation that becomes apparent as an uneven distribution of colors when observing the entire population. Figure 4 shows an example of population after 2,000 years of evolution. In this simulation, the parameters of face shape are sex-influenced, but the skin color is not. We can observe a spacial separation the skin colors. By comparing two magnified images in Figure 4, it is also clear that the figures of male and female are separated but these characteristics are different among races. In the center figure, men are slender and have a bit slant eyes and women are plump and vertically concentrated. On the other hand, men in the right figure have thin eyes but women have bigger eyes. The size of eyes is not directly indexed by genetic parameter, but the vertical spread / concentration causes this effect.

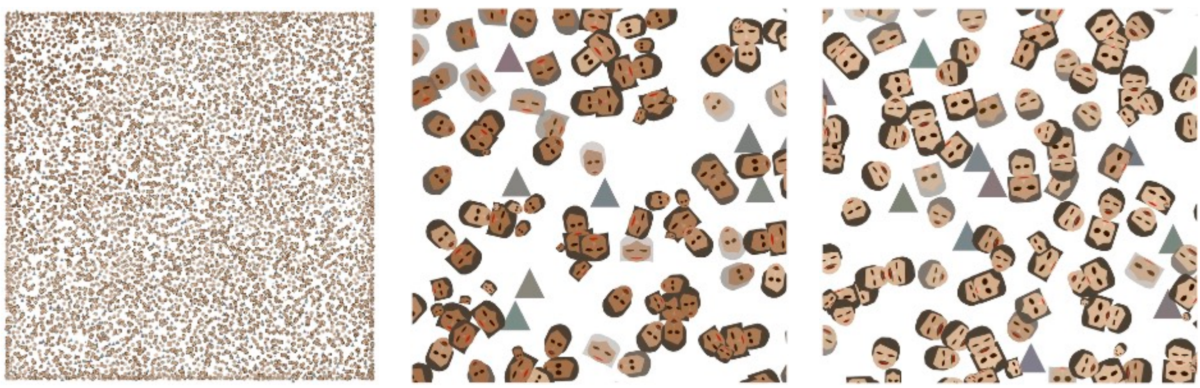

Fig 4.A sample population after 2,000 years of simulation. From left to right: whole world with approx. 6,000 people, magnified view at top left area, and magnified view of middle bottom area. The gray triangles are objects.

4. Utilizing pixel-based images

We have two distinct methods for drawing 2D visuals by the digital computers in general. One is vector representation by a collection of numerical values expressing positions and colors, and the other one is pixel representation by a set of colors for pixels arranged in a 2D lattice structure. The method described above is former one where all of shapes are drawn using 2D Cartesian coordinates in Euclidean space. It has an advantage that prevents from so called jaggy degradation that happens when the resolution of pixel-based image is low. On the other hand, pixel representation is useful to paint arbitrary textures and gradation of colors suitable for digital photograph and sophisticated paintings.

To examine the possibility of an alternative method, we introduced another type of face representation with pixel-based image data. All of equations for deformation described above are applicable to this type by picking up the color value from alternated position in the original image. The coordinate values are calculated using the inverse function for each equation. The computing process seems costly, but not so much when we use the shader of graphic processing unit. It is possible to render each frame image in satisfiable rate for smooth animation.

As our first trial, the face images in Emoji characters were examined. Figure 5 shows examples of deformed face images of male and female adults. Apple's Emoji character set includes seven different faces for ages and genders; that is, baby, boy, girl, adult man, adult woman, elderly man, and elderly woman. It also has a variation of five skin colors. In order to realize a continuous alternation of colors, the face is rendered as a composite image of white and brown skins with blending factor. However, there is no method for continuous changing along the age so far, that means the face shape changes suddenly at the boundary of each age span.

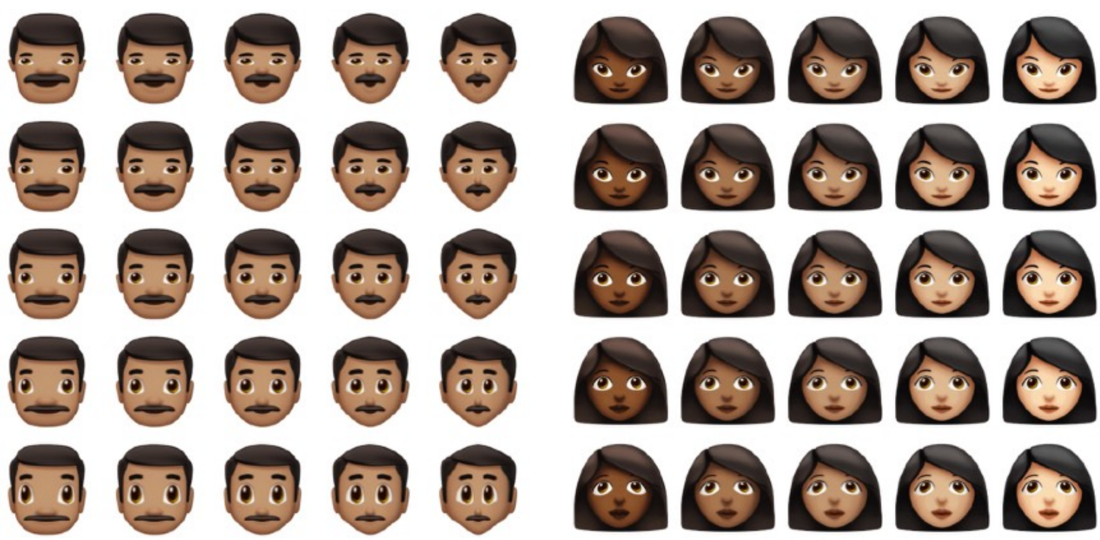

Fig 5. Face variation using pixel-based images extracted from Emoji character set of Apple's macOS Sierra version 10.12.

5. Related works

The researches on parametric human face shapes have been conducted in a several fields in different objectives. One of the well-known applications is to compare a large number of samples represented in numerical vector data. Chernoff's 2D face [2] provides a useful method to intuitive clustering by expressing a vector data into a parametric 2D face shape. It can express maximally 18 parameters, and [2] shows three typical examples for fossil data of 8 measurements, nummulites specimens of 6 measurements, and mineral contents of 12 measurements. The most active field is to generate 3D animation of a variation of facial expressions from a wire-frame model. We can find the most classical research of this stream in [3]. The recent improvement of computational power and machine learning techniques made it possible to generate a realistic facial animation from a few learning examples [4]. These works have the features concerning a drawing technique of human faces by the computer with parametric alternation of shapes as same as our work described here. Although the drawing efficiency is one of the important matter anywhere, the criteria of acceptable computational cost are different among the purposes. When a machine of higher performance becomes available for us, it is also one of the possibility of future extension to render each agent by 3D figure of a whole body and garment.

6. Concluding remarks

We described an extension of our simulator to enable rendering each agent by a face shape. It uses only six parameters to alternate the appearance, but there are more possibilities such as width ratio between top and bottom part, sizes of face parts, and so on. It also possible to introduce emotional expression following the life event happened in the virtual society, such as birth, proposal, acceptance, rejection, separation, and death. These extension is to make the visuals more realistic, however it is also the fact that the realistic visuals is not always effective to provoke the imagination of the audience. We are hoping to improve our installation so that our unique representation will provide higher artistic values.

References

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