Using Contours and Colour Region Boundaries of Photographs in Sculptural Portrait Design

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1. INTRODUCTION

Creating sculptural portraits is one of developing trends of 3D graphics. The development of multimedia and means of communication opened up new fields of their use in video conferencing, robotics, design, advertising actions. A 3D portrait can be created with the view of both achieving photographic resemblance and creating a caricature. However, achieving the desired resemblance degree requires certain artistic skills and time consumption connected with laborious geometric constructions.

Different methods for 3D head model design automation include laser scanning techniques, methods for 3D head model reconstruction from video clips, stereopairs, sets of images acquired at different view angles, methods that represent 3D head models by combining standard models stored in a database. A group of methods is based on the modification of generic models. These methods use less memory, but require paying more attention to specifying individual features of the depicted person.

In the article the method for standard wireframe parametrization is proposed which is based on the modification of a 3D model according to the location of contours and colour region boundaries of a photographic image.

2. STANDARD WIREFRAME DESIGN

We create 3D models using a kinematic method which represents the model as a forming contour and its motion law defined by guide curves [1]. Among its advantages are the simplicity of converting sketches and drafts into a 3D model and a small number of contours required for the model construction. A 3D wireframe consists of the basic section, which is the original forming contour; two basic profiles which define the projections of the object on coordinate planes (in the case of head model construction they correspond to the full-face and half-face photographs); additional sections which define the transformations the forming contour undergoes while moving along its path; 3D profiles which lie on the surface of the model and define its shape.

To form the standard wireframe the sections of maximally different shape were left. The 3D profiles were placed in such a way as to define the shape transformations of the sections and pass through the feature points of the face. The contours were designed with respect to the location of facial muscles and in compliance of proportions based on the Golden Ratio.

3. PROCESSING PHOTOGRAPHS TO OBTAIN INFORMATION ON 3D SHAPE

Photographs can serve as an available source of information on the depicted person. To make the standard model more precise we use full-face and half-face photographs defining the basic profiles of the wireframe. The photographs are taken with uniform illumination coming from the camera, which makes it possible to use the shape from shading approach.

Processing is applied to the images to obtain detailed information on the shape of the face. This processing includes dividing the photographs into gradations of brightness and colour clustering using several parameters [2]. The contours approximating the regions of lower and higher brightness are extracted. The contours and boundaries of the selected regions are represented in vector form.

Using brightness gradations is not always convenient to obtain unambiguous information on the shape. It is necessary to introduce additional clustering parameters to provide a more adequate 3D shape description. An angle between the light source direction **l** and the normal vector **n** to the facial surface can be used as one of such parameters. If the surface is considered an ideal diffuser, then, according to Lambert's cosine law, the cosine of this angle is proportional to intensity reflected by the surface [3]: $I_d = I_s \cos(\mathbf{n}^\wedge\mathbf{l})$, where I_s is source intensity. Adding a number of further simplifications, we can estimate the cosine of the angle between the light source direction and the surface normal. The results of clustering using this parameter provide us with a closer approximation of the spatial characteristics of the facial surface. The way the cluster boundaries are located in the forehead, cheeks, cheek-bones and chin areas is similar to that of the profiles forming the wireframe (Fig. 1).

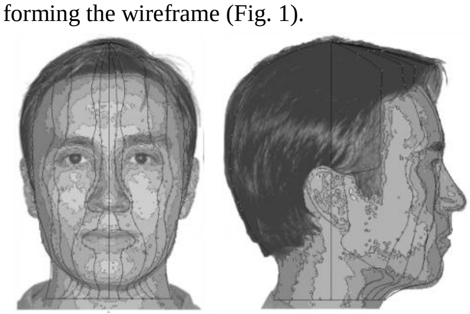

Fig. 1: "Stretching" a wireframe to cluster boundaries

The facial feature points we use include extreme vertical points of the head (vertex and gnathion), paired (eye corners, mouth corners etc.) and unpaired (nose tip, subnasal point, bridge of nose) points. We perform the search for the facial feature points using contours approximating the brightness edges of the images [4]. Some of the feature points in both projections can be found as points of contours with extremal properties. The location of the nose tip, the subnasal point and the bridge of the nose can be successfully determined using contours extracted from the half-face photograph (Fig. 2). It is possible to make up for a deficiency of information on the location of the feature points using the set of equations based on the facial proportions which controls their relative position.

The feature point detection method basing on the extracted contours appears to be more applicable in the case of insufficient illumination quality and when processing images with arbitrary head pose.

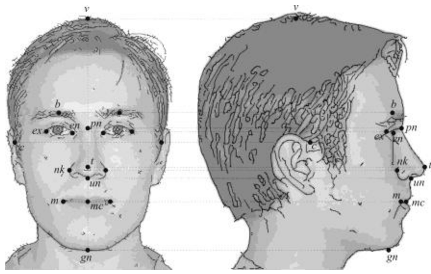

Fig. 2: Feature point detection basing on the extracted contours

4. STANDARD WIREFRAME PARAMETRIZATION METHOD

We use facial feature points to establish the connection between the photographs and the 3D wireframe. Their location on the photographs is determined using the extracted contours, the corresponding wireframe points are also known. Basing on the feature points a simplified face scheme is designed which defines basic 3D head shape elements (Fig. 3). The points forming the simplified model define the location of the 3D wireframe profiles. Their coordinates are stipulated by algebraic relations.

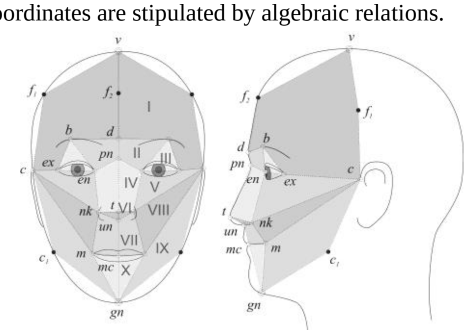

Fig. 3: Simplified face scheme

The first step of standard portrait individualization is matching the wireframe feature points with their projections on the photographs. The simplified face scheme parameters are calculated using the coordinates of the feature point projections. Basing on the scheme the 3D wireframe is designed. Its profiles are constructed by means of interpolating splines. Thus, the standard wireframe is "stretched" to the given points.

Further refinements are made to the model by performing the synthesis of wireframe fragments using contours and colour region boundaries previously extracted from the images. Each of the profiles stretched to the photograph should be transformed into a new one, passing through feature points, both similar in shape to the original one and taking into account the nearby fragments of colour region boundaries. We use smoothing splines to reach this effect [5].

Smoothing splines make it possible to construct a smoothly varying curve passing near the nodes of a specified grid within the given limits of error. The set of the ends of line segments and circular arcs approximating the profile being processed and colour region boundaries located within its neighbourhood acts as a grid in our situation. Let the grid formed by their vertical coordinates be of the form $z_0 < z_1 < \ldots < z_m$.

As the 3D profiles of the wireframe define the way the forming contour transforms while moving along the vertical axis, each vertical coordinate value z can correspond to a unique point of each profile alone. We seek the modified profile in the form of function $S(z)$ which is a smoothing spline defined on a grid $z_0 < z_1 < \ldots < z_m$ minimizing the functional $J(f)=\int_a^b \left(f''(z)\right)^2 dz+\sum_{i=0}^{m}\frac{1}{\rho_i}\left(f(z_i)-y_i\right)^2$ (this condition specifies the compromise between smoothing and approximating), where y_i are the grid node values (in our situation the horizontal coordinate values of the points forming the profile and the colour region boundaries), ρ_i are the weighting factors controlling the spline properties.

Altering the weighing factors we can control the degree of approximation between the resulting contour and each of the original points. We use this feature to keep the feature points of the wireframe from changing their previously defined positions and regulate the wireframe modification degree as well.

The sections of the standard wireframe are corrected automatically. To do this we fix the section positions in relation to the points of the profiles and set the correspondence between the section points and 3D profiles crossing them.

An example of a sculptural portrait designed basing on the given photographs is shown in Fig. 4.

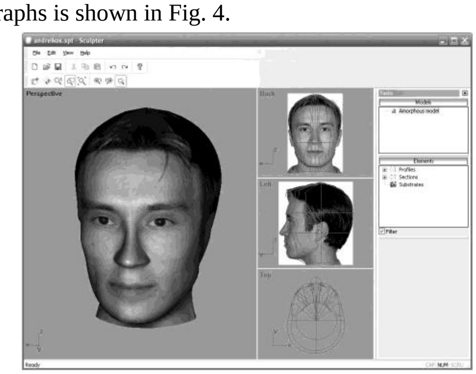

Fig. 4: An example of a sculptural portrait

5. CONCLUSION

The proposed method for standard wireframe parametrization based on the contours and colour region boundaries of the photographs is universal and can be used for creating other geometrically complicated 3D models.

6. REFERENCES

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