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DETECTING AND TRACKING MARKERS ON A HUMAN FACE

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Abstract: The goal of the paper is to develop a standardized, objective, senzitive and accurate quantitative 3D measurement system for evaluating complex facial movements. We aim to detect and track specific markers and create a standard of the facial system that is easily applicable and efficient in the hospital and clinical daily routine. Furthermore, the system will assist patients with facial nerve paralysis and patients with congenital facial malformations during the rehabilitation process by providing feedback of their recovery progress (biofeedback-rehabilitation). The 3D standardized objective measurement system will promote evidence-based medicine and quality control in the field of facial nerve surgery. The data collected will make us able to further optimize therapeutic concepts for future patients.

1. INTRODUCTION

Object tracking is an important task within the field of computer vision. The proliferation of high-powered computers, the availability of high quality and inexpensive video cameras, and the increasing need for automated video analysis has generated a great deal of interest in object tracking algorithms. There are three key steps in video analysis: detection of interesting moving objects, tracking of such objects from frame to frame, and analysis of object tracks to recognize their behavior.

Although facial grading research has been pursued over the last 50 years, none of the existing methods of objective facial measurement has universally been accepted. One of the most serious problems when comparing surgical results, is that each surgeon is using a different method to evaluate the outcome (pacient), making the comparisons between surgical techniques very difficult.

Image analysis for human faces has been an active research topic in image processing, computer vision and psychology. Specific research areas include face detection, face tracking, face recognition, face animation, etc.

The outline of this paper is as follows. In the second section we will present the system for three-dimensional analysis of facial movements. In section 3, we first review the markers which are detected, and show the results.

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2. SYSTEM FOR 3D ANALYSIS OF FACIAL MOVEMENTS

The equipment we usedto experience the 3D analysis of markers on the human face consists of the system for taking the videos, including a comfortable seat in front of two special mirrors arranged under a sharp angle, a calibration grid, a digital video camera (Sony DCR-CX700E). The video is moved to the computer in order to process it.

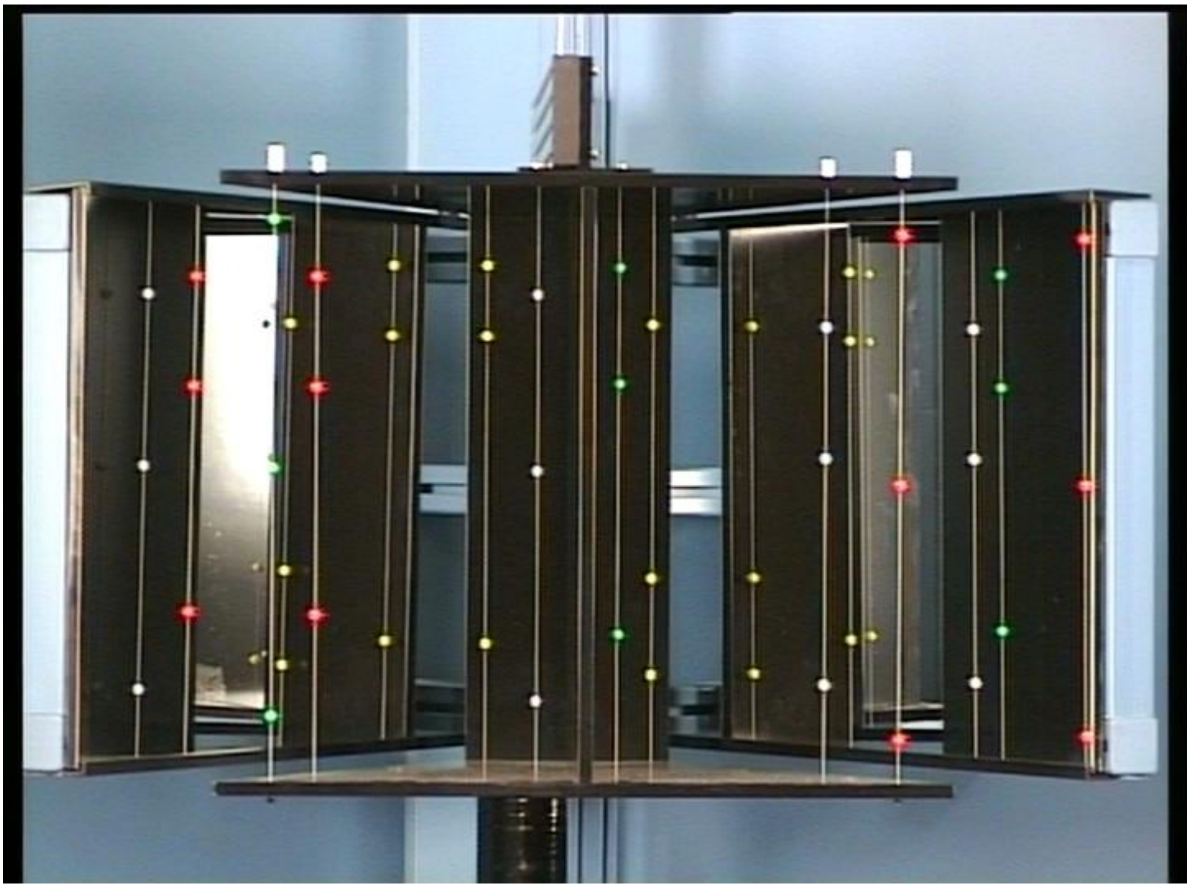

Figure 1. The system of special mirrors arranged under a sharp angle and the calibration grid

At first, the points are marked with a water-resistant pen on the patient’s face. Marking is necessary, because otherwise the points cannot be identified at the same place, especially on the side views of the face of the two mirror images.

To calibrate the system, a calibration grid with small differently colored globes is brought between the two mirrors and is filmed (see Figure 1). Afterward, the calibration grid is removed again, the patient is seated comfortably into the chair, and the head is positioned between the two mirrors so that complete images of the patient's face are obtained, ensuring that all marked points are seen by the camera in both mirrors at the same time (see Figure 1 and Figure 2).

The standardized facial movements of great interest in establishing recovery progress and the efficiency of the treatment are:

- maximal lifting of the eyebrows;
- closing of the eyes as when sleeping;
- maximal closing of the eyes;
- maximal showing of the teeth;
- maximal closing of the eyes and showing of the teeth at the same time;
- smiling with showing the teeth;
- smiling with closed lips;
- pursing the lips and whistling;
- pulling the corners of the mouth downward.

Each of them is recorded by means of the video camera three times.

Figure 2. The pacient with makers on the face placed in the special mirrors arranged

The whole video session does not take more than a few minutes; therefore, fatigue of the facial movements is prevented. This guarantees the accuracy of measuring process and data collecting.

3. DETECTING AND TRACKING THE MARKERs

The video is processed frame by frame for finding the markers on the face. The algorithm is looking for points of white and black color not larger than 2mm on the human face. The detected markers are colored in red. In this way one can see more easier the the found markers (see Figure 3).

We use here the level set method, as a powerful numerical technique for representing the deformation of implicit surfaces. Although implicit surfaces have been used in computer graphics for quite a while, they were mostly used for static modeling and were based on discrete formulations [1]. The *level set method* is based on a continuous formulation using partial differential equations. It allows the representation of the deformation of an implicit surface, which is usually the zero isocontour of a scalar (level set) function, according to various laws of motion depending on geometry, external forces, or a desired energy minimization.

A level set of a real-valued function *f* of *n* variables is a set of the form

$$\{ (x_1,\dots,x_n) \mid f(x_1,\dots,x_n) = c \} \qquad (1)$$

where *c* is a constant. That is, it is the set where the function takes on a given constant value.

A level set or a level surface is $\{p \in \mathbf{R}^3 : f(p) = c\}$, where c is the isocontour value of the surface. An isosurface is useful when the volume itself or varying the isovalue c is of interest; this is often the case when f interpolates a set of discrete sample. Usualy the samples are uniformly spaced physical measurements such as opacity, density, temperature, and stress.

In numerical computations, instead of explicitly tracking a moving surface we implicitly capture it by solving a partial differential equation for the level set function on rectangular grids.

The active contour model is embed as a level set in a suitable image evolution that is determined by a partial differential equation (PDE). In active contour models one places a closed planar parametric curve $C_0 = (x(s), y(s))$, $s \in [0,1]$, around the image parts of interest. Usually, C_0 is embedded as a zero level set into a function u_0: $\mathbf{R}^2 \to \mathbf{R}$ by the signed distance function:

$$u_0(x) = \begin{cases} d(x, C_0), & \text{if } x \text{ is inside } C_0 \\ 0, & \text{if } x \text{ is on } C_0 \\ -d(x, C_0), & \text{if } x \text{ is outside } C_0 \end{cases}, \quad (2)$$

where $d(x,C_0)$ denotes the distance between some points x and the curve C_0.
Let $\Omega := (0,a_x) \times (0,a_y)$ be our image domain in $\mathbf{R}^2$. We consider a scalar image $u_0\{x\}$ on Ω. Then, the geometric active contour model investigates the evolution of u_0 under the PDE:

$$\frac{\partial u}{\partial t} = g(x)|\nabla u| \left(\operatorname{div}\left(\frac{\nabla u}{|\nabla u|} \right) + k \right) \text{ on } \Omega \times (0, \infty), \quad (3)$$

$$u(x,0) = u_0(x) \text{ on } \Omega. \quad (4)$$

One of the numerical implementation is the unified model. We consider the equation, which unifies the geometric and the geodesic model by introducing two additional functions a and b:

$$\frac{\partial u}{\partial t} = a(x)|\nabla u| \left(\operatorname{div}\left(\frac{b(x)}{|\nabla u|} \nabla u \right) + |\nabla u| k g(x) \right). \quad (5)$$

Setting a:=g and b:=1 yields the geometric model, while a:=1 and b:=g results in the geodesic model. Moreover, for a:=b:=1 and k:=0, we obtain the mean curvature motion

$$\frac{\partial u}{\partial t} = |\nabla u| \operatorname{div}\left(\frac{\nabla u}{|\nabla u|} \right), \quad (6)$$

which plays an important role in image denoising and morphological scale-space analysis (see [4]).

The data structure is extremely simple and topological changes are handled easily. The level set formulation works in any number of dimensions and the computation can easily be restricted to a narrow band near the zero level set, see [1] and [6]. We can locate or render the moving surface easily by interpolating the zero isosurface of the level set function. The level set method was originally introduced by Osher and Sethian in [3] to capture moving interfaces and has been used quite successfully in moving objects and free boundary problems as well as in image processing, image segmentation and elsewhere.

Figure 3. The detected markers on the human face

4. CONCLUSION

We use the level set method as a numerical tool to deform and construct implicit surfaces.

The development of a special system with two mirrors in a fixed position together with the calibration unit finally guaranteed a device for measurements of facial movements, which is staying stable during the entire video session of several minutes. The design of the mirror system is suitable for pacients of different ages. The dimensions and the angle between the two mirrors never limited having the frontal view and both mirror images of the face on the same picture. Reducing the time for taking the video to a few minutes ensured that the facial movements never fatigued, and the emotional movements were performed as naturally as possible by the patient.

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