Revista Mexicana de Ingeniería Biomédica

Volumen *Volume* **25** **Número** *Number* **2** **Septiembre** *September* **2004**

Artículo:

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ARTÍCULO DE INVESTIGACIÓN ORIGINAL

REVISTA MEXICANA DE INGENIERÍA BIOMÉDICA
SOMIB

Vol. XXV, Núm. 2
Septiembre 2004
pp 109 - 113

A prototype for automatic image analysis to quantify rehabilitation of chronic facial paralysis

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ABSTRACT

A prototype computarized system was developed to recognize facial features like the pupils of the eyes and the corners of the mouth in video images of patients with facial paralysis. The system uses image processing and the Hough transform for facial feature identification. Once these features are obtained, it can measure the distance between them or to a reference point in the image. The method has been tested with examples of real images of persons undergoing therapy with good results. The purpose of the system is to assist in objective, quantitative rehabilitation in which the patients regain symmetry of their facial musculature and regain control over their facial expressions. This work is important because quantified and objective measures of rehabilitation progress are not widely used in therapy. Semi automated computer techniques promise to not only provide more accurate and effective therapy but also to lower the cost of therapy and may lead to systems that are affordable for home use.

Key Words:
Computer-based rehabilitation, Facial image analysis, Facial paralysis.

RESUMEN

Se ha desarrollado un prototipo de un sistema computarizado para el reconocimiento de características faciales, como las pupilas de los ojos y las comisuras de la boca, en imágenes de pacientes con parálisis facial. El sistema utiliza técnicas de procesamiento de imágenes, en particular la transformada de Hough, para identificar las características faciales. Una vez que estas características han sido localizadas, el sistema calcula la distancia entre ellas o con respecto a un punto de referencia en la imagen. El método ha sido probado con imágenes de pacientes en terapia con buenos resultados. El objetivo del sistema es el de apoyar el proceso de rehabilitación en forma objetiva y cuantitativa, en el cual los pacientes recuperan la simetría de sus músculos faciales y el control sobre sus expresiones faciales. Esto es importante porque no se utilizan en la práctica medidas objetivas y cuantitativas sobre el progreso de la rehabilitación. Las técnicas computarizadas semi-automáticas facilitan una terapia más precisa y efectiva. Además, ayudan a abatir los costos de la terapia, lo que permitirá en un futuro el desarrollo de sistemas más económicos para uso en casa por los pacientes.

Palabras clave:
Rehabilitación asistida por computadora, Análisis de imagen facial, Parálisis facial.

INTRODUCTION

The brain has different mechanisms for reorganizing after central and peripheral lesions. The principal source of clinical evidence for neural plasticity is functional recovery, mostly from anecdotal reports since experimental evidence is only recently becoming available. Preliminary data has demonstrated that it is possible to develop an objective analysis program of the functional results after a rehabilitation program of facial palsy.

Patients with facial paralysis due to cranial nerve VII-XII-anastomoses after tumor resection can improve with the help of a rehabilitation program. Bach-y-Rita and colleagues have developed facial paralysis rehabilitation methodology over the last 25 years[1,2]. These methods include the use of electromyography biofeedback with surface electrodes, behavior modification, and active exercises in front of a mirror. This methodology is considered the state of the art in facial neuromuscular rehabilitation[4].

A major factor limiting the development of neurological rehabilitation research is a lack of objective, quantitative evidence of improvement and validation of rehabilitation methods. Such evidence-based therapy would improve clinical procedures, make them more cost effective, and provide useful data to clinicians. Patient progress reports would be more objective and more useful. Persons with facial paralysis or disfigurement due to tumors, burns or other causes provide an opportunity to apply such an objective system, via computer analysis of images of the face before, during, and after rehabilitation.

Psychosocial issues related to the alteration of emotional expression are also important in the rehabilitation of persons with facial paralysis. The face is the principal means of emotional expression, and so the social disability can be more severe than the physical disability. The availability of quantitative, objective outcome measures of facial movements is of considerable interest to researchers and to clinicians in this field.

We have developed a preliminary computer-based system that can help in objectively evaluating the progress and the results of facial paralysis rehabilitation. The system automatically identifies the pupils of the eyes and corners of the mouth in an image of a person's face. Once these points are obtained the system can measure the distances between them or the distances relative to a reference point in the image. This method has been tested with examples of real images of persons undergoing therapy with good results toward providing objective data about rehabilitation progress.

RELATED WORK

Specific Neuromuscular retraining (NMR) techniques for facial paralysis appeared in the literature 30 years ago. In 1982, Balliet and associates[3] described a comprehensive clinical program that combined electromyography (EMG) feedback, mirror exercises, and detailed, individualized home exercise programs. This clinical program demonstrated improved function with patients more than 2 years postfacial nerve injury. The authors hypothesized that brain plasticity, the capacity of the central nervous system to modify its organization to bring about lasting functional change, explained the acquisition of new motor behaviors in the post acute patient. In 1991, Ross and co-workers[7] compared two treatment groups with a third control group that received no treatment. All patients were more than 18 months post injury in order to control for spontaneous recovery effects.

After comprehensive evaluation, one group was trained with EMG and mirror feedback, while the second group used mirror feedback alone. Patients were reevaluated after 1 year of treatment. A significant difference was found between the treatment groups and the control group. Patients in both treatment groups demonstrated improvements in facial motor control, excursion of movement, and decreased synkinesis. The control group showed no change, or decreased function. A follow-up study 1 year later concluded that gains acquired during treatment had been maintained without continued therapy. We conclude from this research, that the application of NMR techniques specifically designed for the treatment of facial paralysis can effectively reduce sequelae after facial nerve injury.

Objective measures of progress significantly contribute to patients' motivation to practice therapeutic exercises. Patient motivation is key to a successful rehabilitation program[2]. Objective feedback also helps the physician direct the therapy. This method of objective feedback is not limited to facial paralysis and has general applicability to most forms of motor neurorehabilitation in which the current standard of patient-progress feedback is mostly subjective. The potential benefits of computer game motivational therapy for loss of arm movement due to stroke are described in recent research[8]. Computer-based analysis of all types of motor rehabilitation therapy is a step toward objective and effective home-based therapy that can improve patient progress and lower the cost of rehabilitation and medical care.

METHODOLOGY

There are several features in a person's face that can be considered to evaluate their progress while they are undergoing therapy for facial paralysis. Initially, we consider the following measurements:

- Difference in position of the eyebrows (top point) between the "top" position and the rest position.
- Difference in the eye(lid) positions from the open state to the closed state.
- Distance between the center point of the eyes and the corners of the mouth (eyes open).
- Orthogonal distance between the corners of the mouth and an imaginary line between the centers of both eyes.

These measurements are taken with the patient in front of the camera in a fixed position and distance, and considering different expressions (for instance, smiling and not smiling).

To quantify the previously described measurements, several landmarks on the face are identified in the image. In particular, the eyebrows, the pupils, and the corners of the mouth. Our approach is to obtain these features automatically by using image-processing techniques. We have developed algorithms for locating the pupils and the mouth corners, and are working on the detection of the eyebrows.

For pupil detection we developed an algorithm that does the following:

1. Obtain the red plane of the color (RGB) image.
2. Apply an edge detector to enhance the intensity changes (or contrasts) in the image.
3. Apply a threshold to the edge images to keep only "strong" edges.
4. Identify the circles in the image by using the Hough transform.
5. The circles of certain size (diameter) and position in the image are considered to be the pupils.

For the detection of the corners of the mouth, the main steps are:

1. Obtain the red plane of the color (RGB) image.
2. Apply an edge detector to enhance the intensity changes in the lower part of the image.
3. Apply a threshold to the edge images to keep only "strong" edges.
4. Obtain the horizontal lines in the image by using the Hough transform for lines.
5. Identify the extreme (left and right) points of the horizontal lines, which are considered to be the corners of the mouth.

In both cases, an important part of the algorithm is the use of the Hough transform[5,6]. The Hough transform is a general technique that is used to identify any parametric curve in an image, by fitting the "best" curve to a set of points or edges. In our system, we use it for circle detection in the case of the pupils, and for line detection in the case of the mouth.

Once these features are located in the image, some of the proposed measurements can be obtained. We currently report these measurements in pixels, which can easily be transformed to inches (or centimeters) via a camera calibration procedure. The detected features are also shown over the original image so that a visual confirmation by the user is possible.

PRELIMINARY RESULTS

We have tested the methodology with several images obtained from video recordings of two different persons that suffer from facial paralysis. We show the results from one of the images.

Figure 1 shows the face of a person as it was obtained from videotape. By applying the algorithms described in the previous section, we obtained the results shown in Figure 2 and Figure 3. Figure 2 shows the pupils detected in the image of the lady, which are depicted as circles around the pupils. Figure 3 presents the corners of the mouth detected in the same person, indicated by dots in the right and left corners of the mouth. Once these points are detected, we can obtain the distances between them, these are depicted in Figure 4, as currently presented by the computer system prototype. These measurements can be used to semi automatically and objectively determine the amount of movement and control the patient has when responding to therapist directions to volun-

Figure 1. Original image used for the analysis. Some markers (black dots) can be observed, but these were not used by the current image processing system.

Figure 2. Pupils detection. The pupils as identified by the computer system are depicted as circles around the pupils.

Figure 3. Identification of the corners of the mouth, shown as dots over part of the original image.

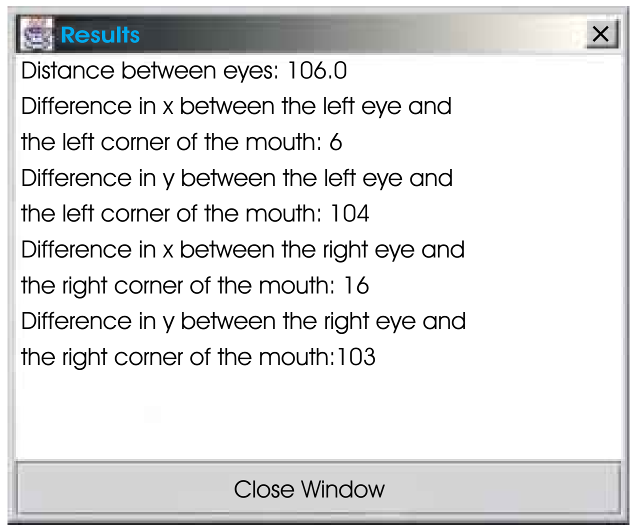

Figure 4. Distances (in pixels) computed by system, as shown in a window of the current prototype.

tarily move the face and make facial expressions. The overall facial symmetry and synkinesis can be quantified.

CONCLUSIONS AND FUTURE WORK

We have developed an initial prototype of a computer system that can help to objectively evaluate the progress of patients with chronic facial paralysis who are undergoing rehabilitation therapy. The system automatically identifies the pupils of the eyes and corners of the mouth in an image of a person's face. Once these points are obtained, the system measures distances between them. This method has been tested with examples of real images of persons undergoing therapy with promising results.

In future work, we plan to detect the eyebrows, and to use a calibration procedure to obtain the distances in absolute units. We are also developing a database in which the images and measurements can be stored and used to follow the progress of the patient undergoing therapy. We plan to use these methods to obtain objective data for clinical trials of rehabilitation of facial paralysis.

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