Biotechnical system for automatic assessment of facial nerve dysfunction rate

E.A. Lavrova[1], A.V. Samorodov[1]

[1]Bauman Moscow State University, Moscow, 2nd Baumanskaya Street, 5, Russia

Contact: lavrovaliz@gmail.com

Introduction

Recently in the field of maxillofacial surgery there is a growing number of patients with facial palsy. Assessment of the facial nerve dysfunction rate is needed for planning of treatment, for monitoring of rehabilitation efficiency and for prediction of patient's state [1]. In clinical experience and research studies to estimate facial nerve dysfunction rate scaling systems are implemented (House-Brackmann, Sunnybrook, Yanagihara, Nottingham, eFACE [2]). As follows from the analysis of the existing methods, all of them have two crucial disadvantages: biased approach and nonuniversality [1].

It is determined that facial nerve dysfunction severity is related to facial muscles dysfunction, which means that it is related to facial lateral asymmetry level. Consequently, it is possible to estimate facial nerve dysfunction rate by applying biometric facial video analysis, based on the measuring of anthropometric features of the facial region. Therefore, development of the biotechnical system for automatic assessment of facial nerve dysfunction rate based on biometric facial video analysis is relevant.

Materials and Methods

In the framework of the present research biotechnical system for automatic assessment of facial nerve dysfunction rate based on biometric facial video analysis is proposed. Figure 1 shows the structure of the system.

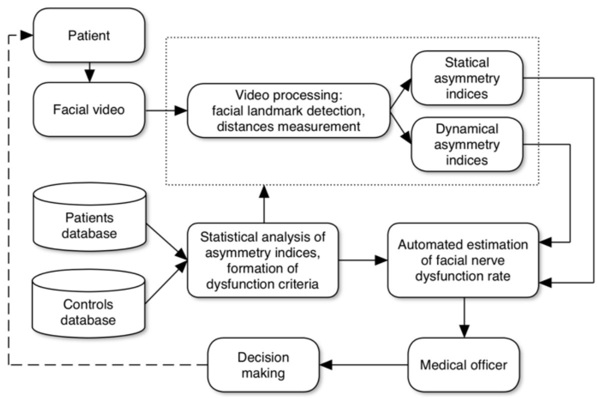

Figure 1: Structure of biotechnical system for automatic assessment of facial nerve dysfunction rate

In the framework of the proposed method, video, containing patient's facial movements, is to be captured, facial video processing (including 2 stages: facial landmark detection and distances measurement) is to be performed, statical and dynamical asymmetry indices, based on relative shift of facial landmarks, are to be estimated. Based on databases of patients and control set, statistical analysis of asymmetry indices is to be held, resulting in formation of dysfunction criteria. Therefore, based on asymmetry indices, automated estimation of facial nerve dysfunction rate is to be performed.

Within this research data recording technique is developed. In its framework, the experimental subject is positioned at a distance of 1 meter to camera (Logitech HD, 1920×1080, 15 fps) against the homogenous background. The face position is frontal. The experimental subject is asked to perform the following movements: demonstration the face at rest, eye squeeze, raising the eyebrows, smiling, forcefully smiling, combining lips a tubule, cheeks puffing, articulating, forced articulating (with overacting amplitude of lips movements).

Facial landmarks detection is implemented with dlib library [3] with 42 enabled facial landmark points of the 68 points MultiPIE/IBUG face model [4] (is shown on Figure 2).

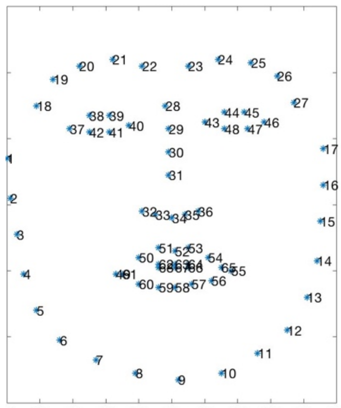

Figure 2: Facial landmarks configuration of the MultiPIE/IBUG face model

Facial asymmetry rate estimations are based on evaluation of relative shift of groups of landmarks. Preliminary facial asymmetry rate estimation (point and integral) is performed for 20 patients and 20 representatives from control set. Point asymmetry rate estimations include asymmetry indices of forehead and mouth regions [5] ("0" corresponds to totally asymmetrical movement, "1" corresponds to totally symmetrical movement).

Forehead asymmetry rate is based on estimation of the rate of relative shift of eye and eyebrow points from left and right forehead regions (points P_{18}-P_{22} respective to points P_{37}-P_{42} and points P_{23}-P_{27} respective to points P_{43}-P_{48}). The basic principles are described below:

a) estimation of mean eyebrow points LEB and REB:

$$LEB = \frac{1}{5}\sum_{i=18}^{22} P_i\,, REB = \frac{1}{5}\sum_{i=23}^{27} P_i,$$

b) estimation of mean eye points LEC и REC:

$$LEC = \frac{1}{6}\sum_{i=37}^{42} P_i\,, REC = \frac{1}{6}\sum_{i=43}^{48} P_i,$$

c) estimation of distances D_{REB} and D_{LEB} between mean eye and eyebrow points on the left and on the right sides:

$$D_{LEB} = d(LEB, LEC), D_{REB} = d(REB, REC),$$

where d – distance measure,

d) estimation of relative shifts Δ_L^f and Δ_R^f of the forehead region points on the left and on the right sides:

$$\Delta_L^f = \left|\max_i\left(D_{LEB_i}^{test}\right) - \bar{D}_{LEB}^{rest}\right|,$$

$$\Delta_R^f = \left|\max_i\left(D_{REB_i}^{test}\right) - \bar{D}_{REB}^{rest}\right|,$$

where D_{LEB}^{rest} and D_{REB}^{rest} – distances between mean eye and eyebrow points on the left and on the right sides at rest, D_{LEB}^{test} and D_{REB}^{test} – distances between mean eye and eyebrow points on the left and on the right sides during the facial movements, i – number of videoframe,

e) estimation of indice r_f, which reflects the shift between left and fight parts of forehead region:

$$r_f = \begin{cases} \dfrac{\Delta_R^f}{\Delta_L^f} \text{ if } \Delta_L^f > \Delta_R^f \\ \dfrac{\Delta_L^f}{\Delta_R^f} \text{ otherwise.} \end{cases}$$

Mouth asymmetry rate is based on estimation of the rate of relative shift of mouth corners points from left and right sides and mouth center points (points P_{49} and P_{55} respective to points P_{52}, P_{63}, P_{67}, P_{58}). The basic principles are described below:

a) estimation of mean distances D_{LM} and D_{RM} between mouth corners points P_{49} and P_{55} and mouth center points $P_{52}, P_{63}, P_{67}, P_{58}$:

$$D_{LM} = \frac{1}{4}\big(d(P_{49}, P_{52}) + d(P_{49}, P_{63}) + d(P_{49}, P_{67}) + d(P_{49}, P_{58})\big),$$

$$D_{RM} = \frac{1}{4}\big(d(P_{55}, P_{52}) + d(P_{55}, P_{63}) + d(P_{55}, P_{67}) + d(P_{55}, P_{58})\big),$$

b) estimation of shifts Δ_L^m and Δ_R^m from the left and from the right sides:

$$\Delta_L^m = \left|\max_i(D_{LM_i}^{test}) - \bar{D}_{LM}^{rest})\right|,$$

$$\Delta_R^m = \left|\max_i(D_{RM_i}^{test}) - \bar{D}_{RM}^{rest})\right|,$$

where $\bar{D}_{LM}^{rest}$ and $\bar{D}_{RM}^{rest}$ – mean distamces between mouth corners points and mouth center points at rest, $D_{LM_i}^{test}$ and $D_{RM_i}^{test}$ – distances between mouth corners points and mouth center points during the facial movements, i – number of videoframe,

c) estimation of indice r_m, which reflects the shift between left and fight parts of mouth region:

$$r_m = \begin{cases} \dfrac{\Delta_R^m}{\Delta_L^m} \text{ if } \Delta_L^m > \Delta_R^m \\ \dfrac{\Delta_L^m}{\Delta_R^m} \text{ otherwise.} \end{cases}$$

Integral asymmetry rate estimations include distances between relative shift curves ("0" corresponds to totally symmetrical movement).

Results

Table 1 shows the results of experimental evaluation of asymmetry indices of forehead region during eye squeeze, raising the eyebrows, smiling, forcefully smiling, combining lips a tubule, cheeks puffing. The median and also lower and upper quartiles are presented. The presented asymmetry indices correspond to point asymmetry rate estimation.

Table 1: Asymmetry indexes of forehead region

Exercise	Control	Patients
Eye squeeze	0.94	0.88
Raising the eyebrows	0.95	0.68
Smiling	0.86	0.09
Forcefully smiling	0.94	0.74
Combining lips a tubule	0.72	0.47
Cheeks puffing	0.08	0.39

Table 2 shows the results of experimental evaluation of areas between relative shift curves of forehead regions during articulating, forced articulating. The presented values of areas correspond to integral asymmetry rate estimation.

Table 2: Areas between relative shift curves of forehead regions (pixels per frame)

Exercise	Control	Patients
Articulating	75	94
Forced articulating	98	122

Discussion

Performed point asymmetry rate estimations are based on peak amplitudes acquired from series of videoframes. Therefore, in general, peak amplitudes from different videoframes can be used for single asymmetry rate estimation. This results in upward bias of asymmetry rate estimation and downward bias of test-sensitivity in case of facial nerve dysfunction. Consequently, it is reasonable to use integral asymmetry rate estimations based on dynamical features acquired from each frame.

Conclusions

According to results of preliminary facial asymmetry rate estimation, it's reasonable to develop integral facial asymmetry rate based on dynamic features. At this moment set of these features is under exploration.

References

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