A perception-based approach for assessing facial symmetry and attractiveness from optically acquired surface data

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Based on optically acquired 3D data of faces local deviations from symmetry can be measured. Asymmetry indices can be defined, which correlate with perception. These correlations are enhanced by weighting higher asymmetries in the horizontal center of the face, by including local curvature or by including color asymmetry.

1 Introduction

Contact-free optical acquisition methods like the fringe projection technique provide colored 3D shapes which can be used e.g. for the computer aided design of facial prostheses. For this purpose, symmetry has to be taken into account as an important factor affecting esthetics. Thus, its restoration is an essential task in maxillofacial surgery as well.

While there is a well-established framework for calculating a quantitative measure for perceived colors from measured spectra, a similar link between measured and perceived symmetry is missing yet. In this contribution it is investigated how facial asymmetry can be quantified from 3D shape with the aim of enhancing its correlation with perceived symmetry and attractiveness. As perceptually relevant parts of the face are expected to be situated near the midline, central parts are emphasized during calculation of an asymmetry index. Likewise, regions exhibiting a pronounced curvature value are weighted higher than flat ones. These two measures combined with calculated color differences result in statistically significant correlations between objective asymmetry values and subjective symmetry and attractiveness ratings.

2 Optical 3D surface acquisition

The facial surface is acquired using a fringe projecting system with three calibrated cameras. This measurement results in a cloud of 3D points with assigned true colors forming a triangle mesh.

3 Calculation of the asymmetry index

On the basis of the colored point cloud an asymmetry index AI_{geom} is calculated per face. It indicates the degree of deviation from perfect bilateral symmetry. First, a symmetry plane is calculated applying a multi-stage ICP-based matching procedure to the facial surface and its mirrored version. Then, spatial distances between the original and the mirrored and matched surface are determined and averaged over all points within the face. This average is finally divided by the size of the face in order to prevent asymmetries in large faces to be overestimated [1].

4 Perception-based asymmetry indices

Once having obtained a spatial distribution of asymmetry values in the face, the decision which parts to put more or less weight on when calculating an asymmetry index can be made from the viewpoint of perception. Since strongly curved regions appear with higher contrast under even illumination, they are potentially more relevant for perceived symmetry and attractiveness than rather flat ones. Following this notion, the local mean curvature is calculated for each point from a paraboloid fitted to a surface subset of size $N \times N$ points. Its absolute value to the power of z is introduced here as a weighting function for point-wise asymmetries. These weighed values are again averaged and divided by the size of the face to obtain the face-specific index $AI_{\mathrm{curv}}(N,z)$. N represents a smoothing factor and z quantifies, whether subtle or only strong curvatures are emphasized.

A second weighting strategy is based on the assumption that facial regions of particular relevance for perception are located in the horizontal center. The corresponding weighting function is a Gaussian of the distance of each point to the symmetry plane, which has been determined from the complete facial shape. The standard deviation σ of the Gaussian is varied. This weighting strategy delivers the central asymmetry index $AI_{\mathrm{center}}(\sigma)$.

5 Color asymmetry index

Not only the asymmetry of the facial shape but also its color asymmetry is assumed to impact facial esthetics. In order to determine a color asymmetry, index distances in CIELAB color space between the facial surface and its mirrored copy are evaluated instead of spatial distances. Averaging over the complete face then results in the index AI_{color} [2].

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6 Survey for subjective ratings

In order to investigate correlations between objective (weighted) asymmetry indices and perceived symmetry and attractiveness of faces, stimuli are created from the acquired 3D surface data. Each stimulus shows the face in true colors rotating by 40° around its vertical axis for 4 s [2][3]. After this sequence has been displayed, a subject is asked to rate the symmetry and the attractiveness of the face on visual analog scales. In total, the faces of 30 healthy adults are presented to 100 adult raters. For the following correlation analyses, the survey results are averaged per rater and per rated item.

7 Correlations of objective AIs with ratings

Fig. 1 shows correlation coefficients according to Pearson between mean rated symmetry and the curvature-weighted asymmetry index AI_{curv} for the subset size N varied between 3 and 25 (only odd numbers) and for z ranging from .2 to 8.0 in steps of .2. While the correlation with the unweighted AI_{geom} already is highly significant (r = -.63, p < .001), the correlation is still slightly increased by the weighting. In Fig. 2, a similar plot is displayed for rated attractiveness. By curvature-weighting the correlation with attractiveness is increased from a non-significant one (AI_{geom}: r = -.31, p = .100) to a highly significant one (r < -.5, p < .005, area enclosed by the blue line). The strategy of weighting higher asymmetries near the horizontal center of the face leads to significant correlations of AI_{center} with rated symmetry and attractiveness at the same time (Fig. 3). The value of σ = .150 is identified as a good trade-off between both rated items.

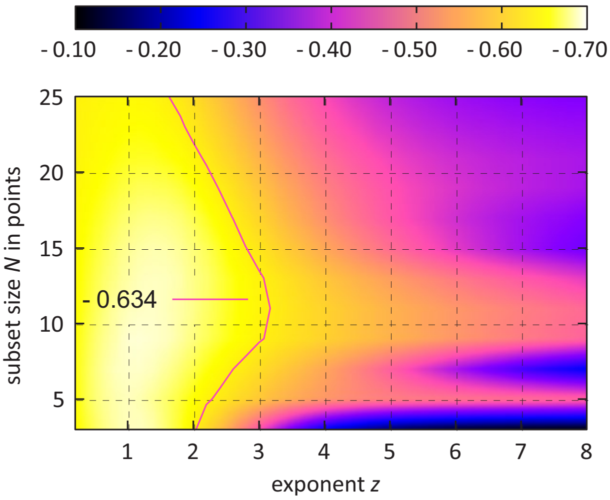

Fig. 1 *Correlation coefficients r displayed in pseudocolors between rated symmetry and calculated* AI_{curv}. *The magenta line denotes r for the unweighted* AI_{geom}.

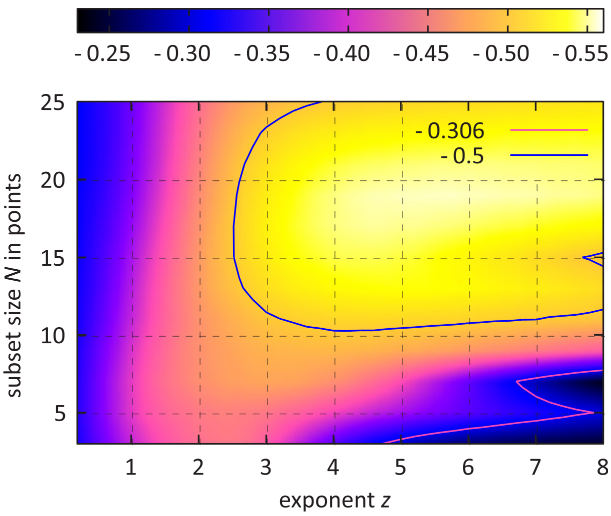

Fig. 2 *Correlation coefficients r displayed in pseudocolors between rated attractiveness and calculated* AI_{curv}. *The magenta line denotes r for the unweighted* AI_{geom}.

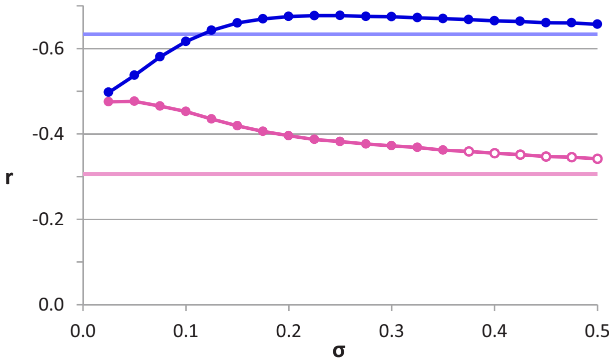

Fig. 3 *Correlation coefficients r of rated symmetry (blue) or rated attractiveness (magenta) with calculated* AI_{center} *vs. the width σ of the Gaussian. Lines in light colors mark the corresponding correlation levels for the unweighted* AI_{geom}. *Circle outlines indicate non-significant correlations.*

Neither AI_{geom} nor AI_{color} show significant correlations with rated attractiveness. But the product $AI_{geom} \cdot AI_{color}$ of both, a measure comprising shape and color information simultaneously, correlates significantly with the subjective attractiveness ratings (r = -.38, p = .039). Moreover, its correlation with symmetry ratings is the highest observed in this study (r = -.73, p < .001) [2].

References

[1] P. Berssenbrügge, N.F. Berlin, G. Kebeck, C. Runte, S. Jung, J. Kleinheinz, D. Dirksen, "2D and 3D analysis methods of facial asymmetry in comparison," in *J Cranio Maxill Surg* **42**: e327-e334 (2014)

[2] P. Berssenbrügge, M. Lingemann-Koch, A. Abeler, C. Runte, S. Jung, J. Kleinheinz, C. Denz, D. Dirksen, "Measuring facial symmetry: a perception-based approach using 3D shape and color" in *Biomed Eng* **60**(1): 39-47 (2015)

[3] J. Ostwald, P. Berssenbrügge, D. Dirksen, C. Runte, K. Wermker, J. Kleinheinz, S. Jung, "Measured symmetry of facial 3D shape and perceived facial symmetry and attractiveness before and after orthognathic surgery," in *J Cranio Maxill Surg* **43**(4): 521-527 (2015)

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