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MULTI-THRESHOLD LIP CONTOUR DETECTION

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ABSTRACT

In this work, we propose a novel, multi-threshold method for lip contour extraction from high-resolution static lip images acquired in an uncontrolled environment and emphasizing on the contour details.

The introduced method is a "Divide and conquer" approach. We broke the problem of lip contour extraction into two base sub-problems of locating the upper and lower lip contours using a novel threshold selection algorithm and combining them into the solution for the original lip contour.

The method was evaluated on a set of lip images taken from healthy subjects as well as on a set acquired from elder people with degraded lip shapes, and diagnosed with solar cheilosis.

Our approach is a low complexity algorithm for robust and accurate lip contour extraction revealing shape details, which might be of value in diverse applied fields such as automated lip biometric and monitoring patients with affected lip contour

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1. INTRODUCTION

Automatic lip contour detection :

- Essential issue in face image analysis *(human-machine interaction, emotion analysis, person identification and bimodal speech recognition).*
- Elaborate task *(inter-person variability, presence or absence of teeth, tongue, moustaches or beards, low contrast between lip and skin, high deformable level of lips, illumination conditions)*

Several segmentation methods based on different methodologies have been proposed [1-3]
There is no clear answer which algorithm is optimum, mainly for two reasons:

1. Different accuracy requirements for different applications
2. No benchmark databases and quantitative methods to evaluate performance

Existing techniques focus on lip area detection in low-resolution lip images

Our aim: To extract detailed lip contours from high-resolution static images. The latter might be of value in diverse applied fields as in automated lip biometric and monitoring patients with affected lip contour (Solar cheilosis)

2. LIP EXTRACTION

2.1 Transform images from RGB to YIQ color space. Retain Q channel for lip detection
✓Otsu's metric ranked Q component first among 33 color transforms [4]
✓lip-skin differentiation based on Q component is not affected by the presence of facial hair [5]

2.2 Lip corners detection and image spilt into upper and lower part (Figure 1).

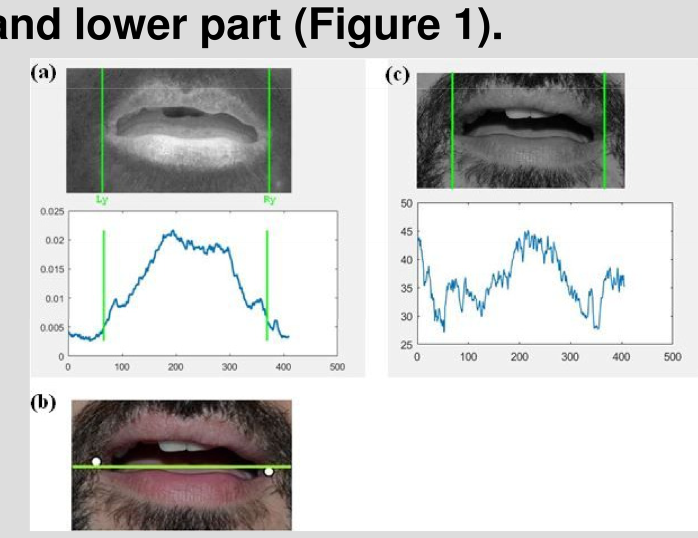

Figure 1: Lip corner detection and image split

$(L_x,L_y),(R_x,R_y)$: coordinates of left and right lip corners
L_y,R_y : most left and most right detectable changes of column wise standard deviation of Q matrix
L_x,R_x: coordinates with maximum Q value of $Q(i,L_y)$ and $Q(i,R_y)$.

Modification of a method proposed by Liu et al. [2]-Figure 1c

2.3 Base sub-problem solution
Working hypothesis:
***"There exist effective threshold values of Q chromaticity that adequately separate skin pixels from upper (lower) mouth area including the upper (lower) lip regions"* (Figure 2).**

Such threshold values are estimated for each image part, by examining the contours produced by several candidate thresholds of chromaticity Q and selecting the best one according to a novel separation criterion (**Figure 3;eq. 1)**

$$D = \sum_{i=1}^{l}\sum_{j=1}^{l}\frac{|q_i^{up} - q_j^{down}|}{l^2} \quad (1)$$

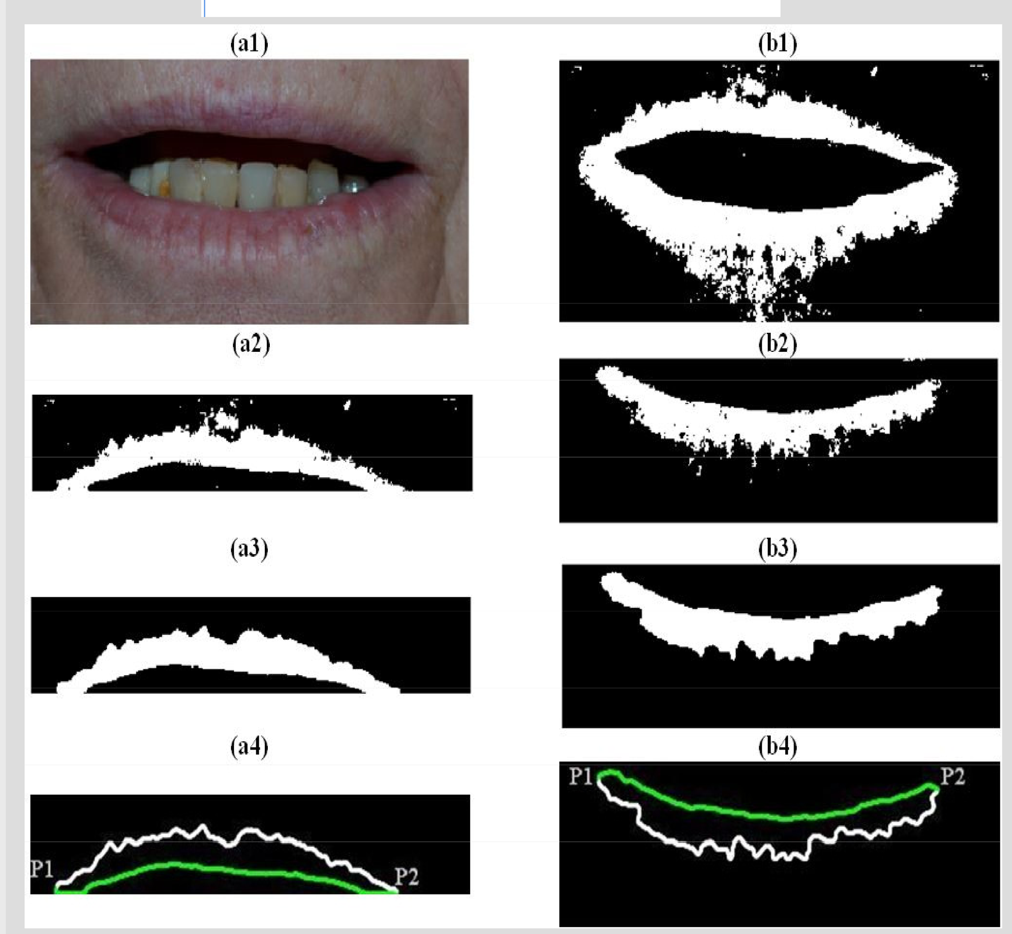

Figure 2: Lip image **(a1)** and the corresponding result of applying Otsu's threshold in Q chromaticity **(b1)**. Processing steps **(a2-a4 ;b2-b4)**

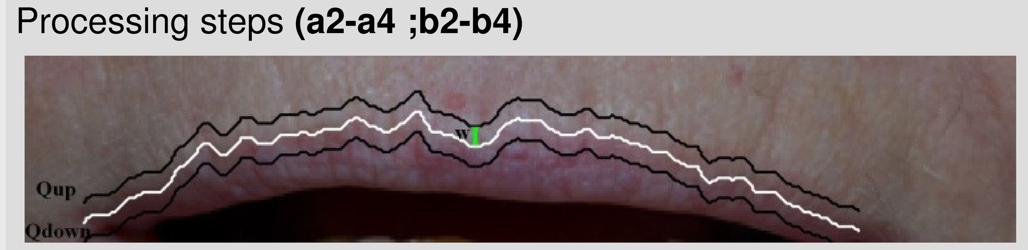

Figure 3: Upper lip contour resulted by maximizing the normalized sum of pairwise Q intensity Euclidean distances between lip and skin pixels that lie at a vertical distance **w** to contour pixels

Missing points around the lip corners are computed by interpolating two second-degree polynomials that fit each extracted lip contour, in a least-squares sense, with the constraint to pass from the lip corners **(Figure 4).**

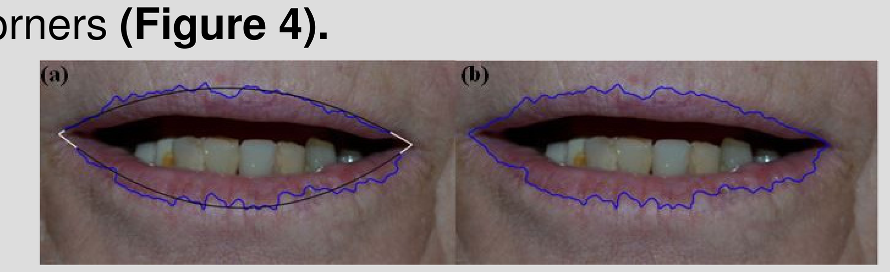

Figure 4. Computation of missing points **(a)**.Final lip contour **(b)**

Parameters' selection & Quantitative evaluation
•Ground truths (N=57 healthy & N=30 solar cheilosis subjects)
•Average Hausdorff distance
•Upper, lower, whole lip contour
•Comparison: Otsu's, k-means (k=2),active contours (Chan-Vese method)

3. RESULTS AND DISCUSSION

Table 1: Upper and lower lip contour quantitative evaluation using Hausdorff metric

N=57 Healthy subjects		
w	**Upper Lip**	**Lower Lip**
3	0.595	0.361
5	0.491	0.324
7	0.417	0.298
9	0.482	0.329
N=30 Solar Cheilosis subjects		
w	**Upper Lip**	**Lower Lip**
3	0.701	0.594
5	0.607	0.601
7	0.581	0.585
9	0.607	0.597

Table 2: Comparison results using Hausdorff metric

N=57 Healthy subjects		
	Upper Lip	**Lower Lip**
Multi-threshold	0.417	0.298
Otsu	0.677	0.337
Active contours (Chan-Vese)	0.754	0.316
k-means k=2	0.781	0.325
N=30 Solar Cheilosis subjects		
	Upper Lip	**Lower Lip**
Multi-threshold	0.581	0.585
Otsu	0.596	0.611
Active contours (Chan-Vese)	1.374	1.063
k-means k=2	1.465	0.999

➤Optimal results were obtained for both healthy and solar cheilosis (SC) lip images, for distance w equal to 7 **(Table 1)**

➤Optimal threshold values are in Otsu's neighborhood:
Th=[Ot-k*step,Ot+k*step], k=16, step=0.001
The search for optimal thresholds is reduced dramatically

➤Multi-threshold method outperformed Otsus' thresholds k-means and active contours algorithms **(Table2 & Figure 5)**

➤ In healthy subjects, the main difficulty in detecting accurate lip contours, originates from the upper lip, mainly due to the lower chromaticity contrast between upper lip and skin

➤In patients with SC (which are also elder people) the accuracy to detect both upper and lower lip contour is even more challenging.

➤Multi-threshold approach can handle more efficiently both the low contrast between upper lip and skin and the affected lips of older adults **(Table 2).**

➤The method evaluated using our lip database (lip clip was ~ **270x350** pixels).A notable difference with respect to previous works, where the evaluation was on lip area using face databases with very low image resolution (clipped lip is ~**40x70** pixels).

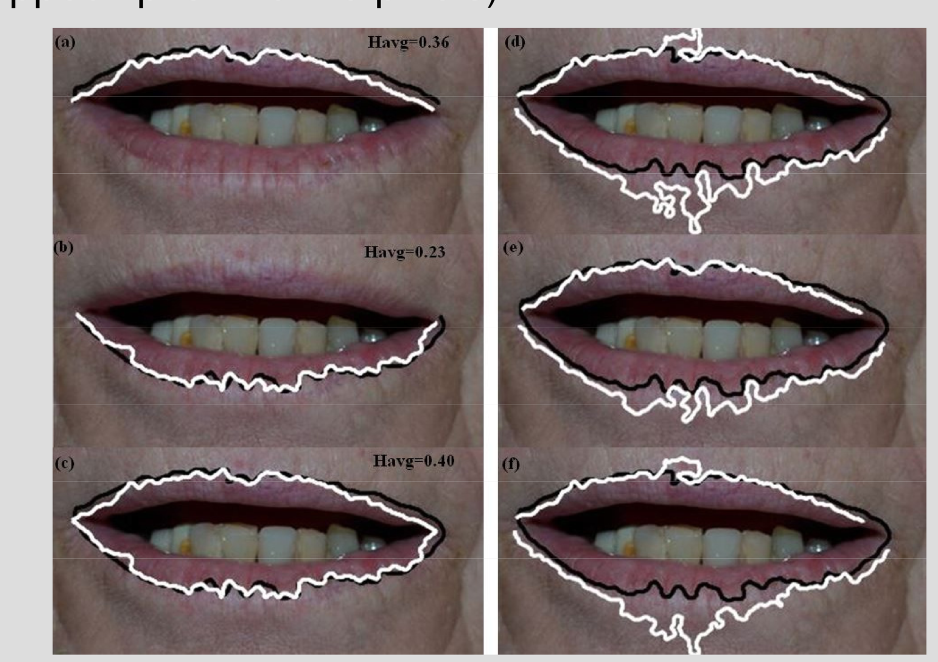

Figure 5: Hausdorff distance estimates the "closeness" of the estimated lip contour (white line) to the ground truth (dark line) for the upper lip **(a)**, lower lip **(b)** and overall lip contour **(c)**. "Divide and conquer" approach for Otsu's method **(d)**, active contours **(e)**, and k-means **(f)**

5. REFERENCES

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