Automatic segmentation of tooth images: Optimization of multi-parameter image processing workflow

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MOTIVATION

The Hunter-Schreger Bands (HSB) are an optical phenomenon on the tooth enamel surface, which seems to be unique for every tooth. Hence, they have the potential to be used for human identification (Ramenzoni and Line, 2006). A specific pipeline for this new approach is currently in development for biometric application (Fig. 1). The main problem for the segmentation step is the subjective human perception of the useful HSB region borders, leading eventually to either quality degradation (for too large selected regions) or loss of information (for too small selected regions). Moreover, it is very time-consuming. To automate the process, a specific image processing pipeline was developed, which we call anisotropy-based segmentation. It involves three parameters, the tuning of which to achieve the best possible model performance is the goal of the presented work. Example results are shown in Fig. 2.

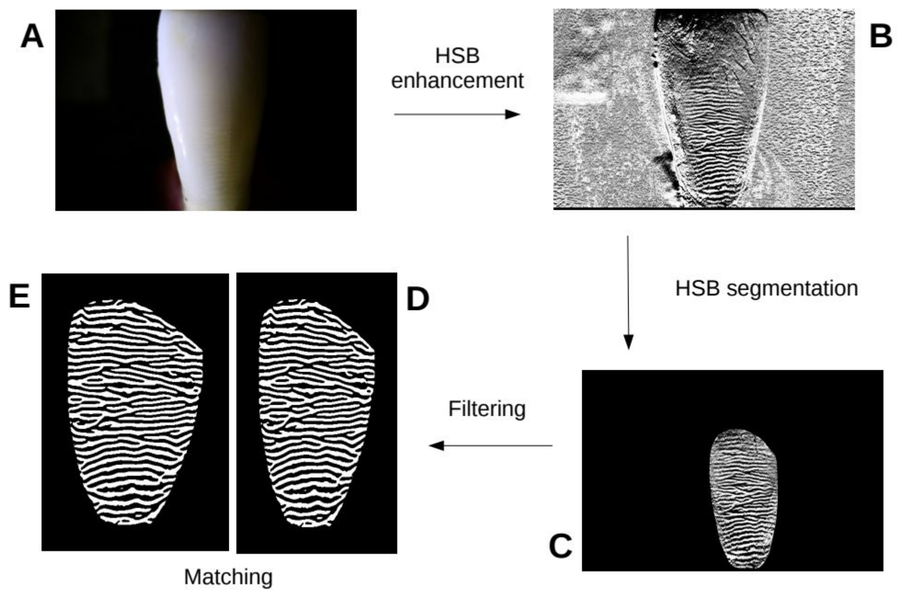

Figure 1. Tooth biometrics workflow. The workflow starts with original photography of tooth crown exposed to side lighting (A), followed by HSB enhancement (Arrieta et al., 2018). Then, the enhanced HSB image (B) is segmented (C) and filtered into a binary noiseless image representing the tooth HSB pattern (D). This might then be stored as template or be compared against tooth templates registered in a database (E) using a matching algorithm.

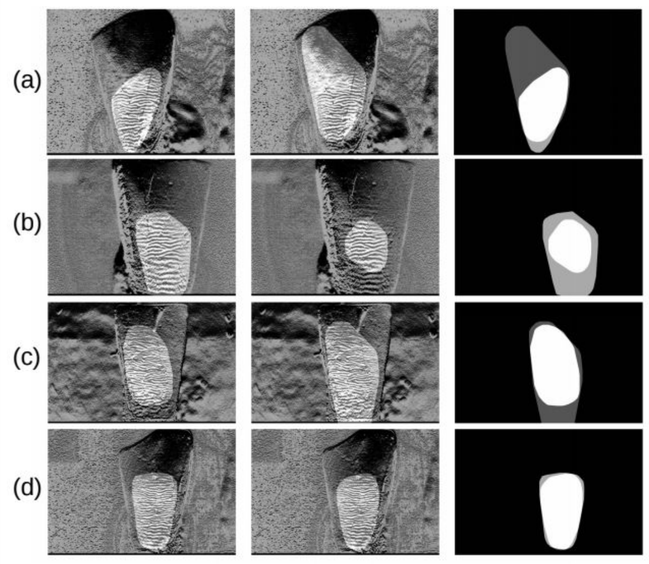

Figure 2. Examples of HSB segmentations. Left to right: ground truth; automatic segmentation; overlap of masks (light gray - ground truth; dark gray - automatic mask). (a) Too large region. (b) Too small region. (c) Slightly larger region. (d) Desirable result.

METHODS

Dataset

124 images (31 teeth, 4 images each)

Ground truth masks are obtained from manual segmentation as the largest suitable HSB region.

Parameters

u is linked to the initial image size reduction. The higher u is, the larger is the resized image.

kx/ky is the blurring operator shape.

α is the factor by which mask shape borders are smoothed. The higher α is, the less the mask shape is smoothed.

Evaluation

IOU + EMSOU + EASOU = 1

Experimentally obtained values

kx/ky = ⅓ ; u = 200 ; α = 0.7

Parameter sampling

(kx, ky) ∈ {(86, 86), (61, 122), (50, 150), (43, 172), (39, 195)}
→ kx/ky ∈ {1, ½ , ⅓ , ¼ , ⅕ }

u ∈ {100, 150, 200, 250, 300}

α ∈ {0.5, 0.6, 0.7, 0.8, 0.9}

125 parameter combinations

HSB SEGMENTATION WORKFLOW

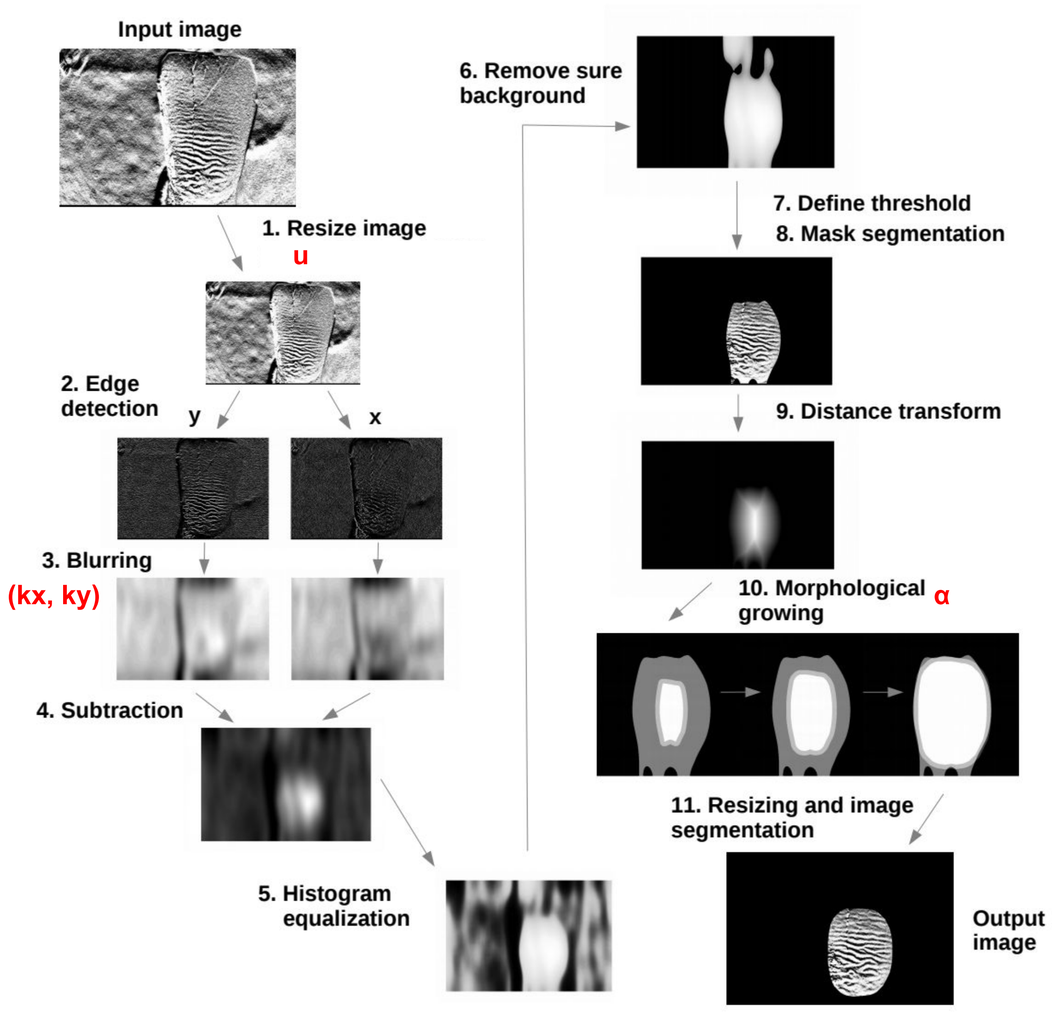

Figure 3. Anisotropy-based segmentation workflow. The steps where parameters are used are marked with red: (1) for parameter u; (3) for the parameter pair (kx, ky); and (10) for parameter α.

RESULTS

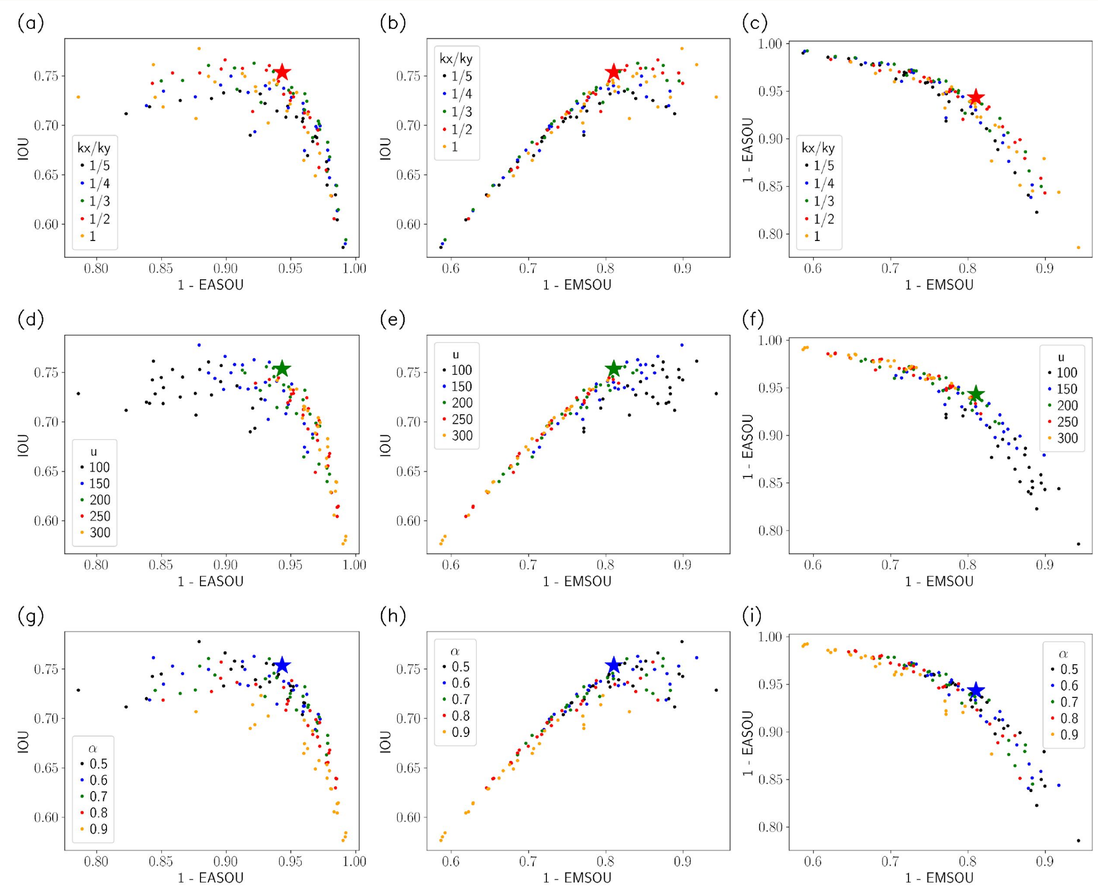

Figure 4. Scatter plots of all descriptor relations according to parameters kx/ky (a,b,c), u (d,e,f), and (g,h,i). The * symbol represents the best model setting.

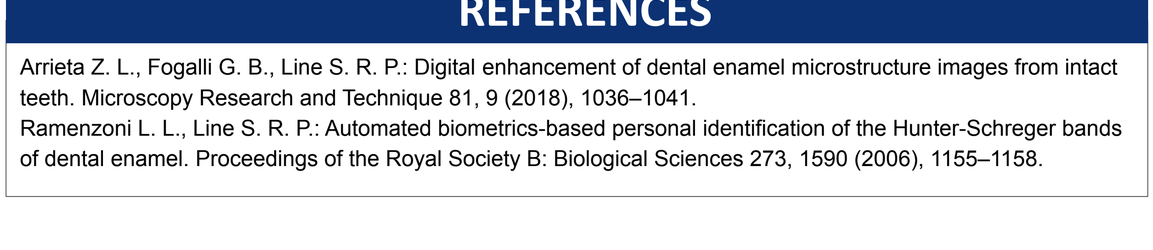

Figure 5. Boxplots for parameters kx/ky (a), u (b), and α (c).

LIMITATIONS AND FUTURE WORK

Limitations

- Some segmentations still have a poor quality (Fig. 2a,b).
- Better performance would reduce post-processing computation.

Future work approaches

- Compute mask attributes like shape descriptors, curvature, and orientation.
- Use of link-and-brush, e.g. using parallel coordinate plots, to explore the relation between segmentation parameters and mask attributes.

REFERENCES

Arrieta Z. L., Fogalli G. B., Line S. R. P.: Digital enhancement of dental enamel microstructure images from intact teeth. Microscopy Research and Technique 81, 9 (2018), 1036–1041.

Ramenzoni L. L., Line S. R. P.: Automated biometrics-based personal identification of the Hunter-Schreger bands of dental enamel. Proceedings of the Royal Society B: Biological Sciences 273, 1590 (2006), 1155–1158.