Image Segmentation from Shadow-Hints using Minimum Spanning Trees

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BACKGROUND

Image segmentation in RGB space is a difficult task. High-contrast textures can lead to over-segmentation while similarly coloured objects might not be separated.

Previous Work:

Learning-Based [4]
- ✚ robust performance
- ━ need for training data

Classic [2]
- ✚ no training needed
- ━ error prone

MAIN IDEA

Foreground objects cast shadows onto background objects. Therefore, transitions from light to shadow occur on object boundaries and reveal details about spatial structure of the scene.

Using a moving light source together with a static camera allows tracing object contours [7]. However, these contours are typically not watertight.

Previous work on interactive sketch colouring has shown that the Delaunay triangulation of contour points captures all the key properties needed for segmentation [6].

We solve the contour completion problem on the face graph of the Delaunay triangulation by modifying minimum spanning tree algorithm [5].

CONCLUSION

Our approach achieves results that are comparable to state-of-the-art but without the need for training. Since the segmentation runs in real-time, an interactive modification of the user-parameters is feasible.

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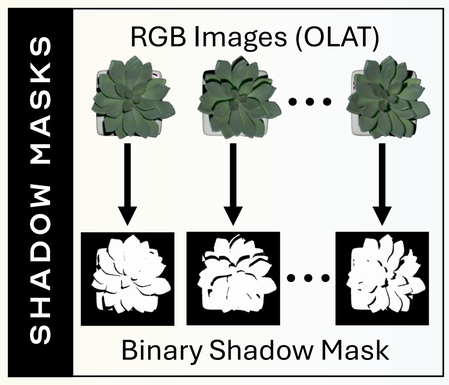
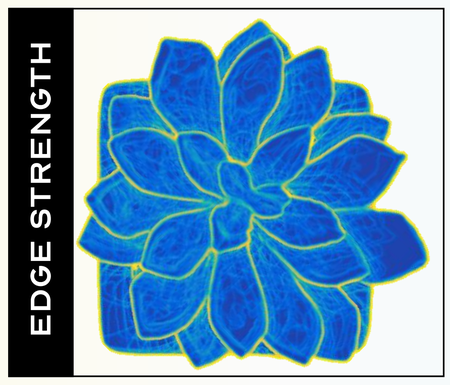
METHOD



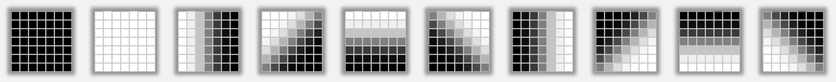
INPUT

We use binary shadow masks for a one-light-at-a-time (OLAT) image squence as input. Such shadow masks are commonly generated as a by-product of photometric stereo, e.g. [3]

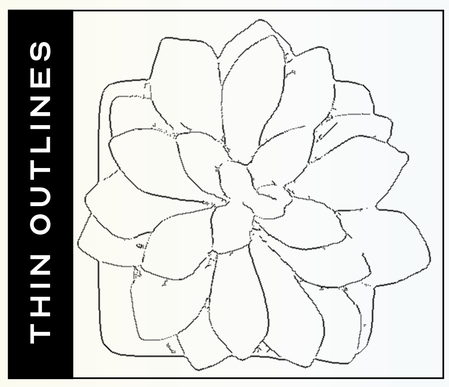


SHADOW EDGE DETECTION

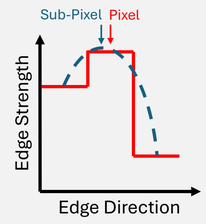
1. **Detect** light-to-shadow transition via L^2 template matching



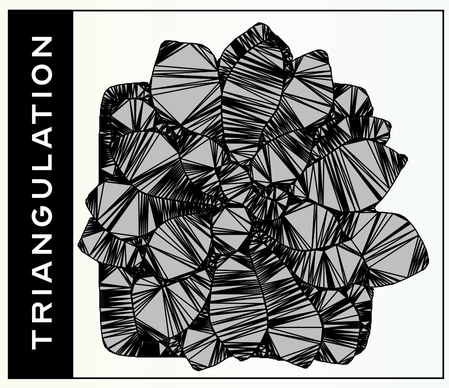
2. **Filter** based on consistency between transition direction and light position [7]
3. **Combine** into a pixel-wise edge strength and direction



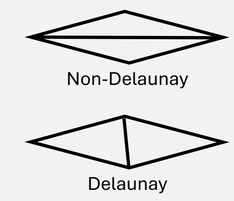
OUTLINE EXTRACTION



1. **Suppress** non-maxima and
2. **Apply** double thresholding, cf. Canny Edge Detector [1]
3. **Move** to sub-pixel positions via quadratic fit



DELAUNAY TRIANGULATION



1. **Delaunay triangulate** detected contour points
2. **Remove** triangles covering the image background

SEGMENTATION

1. **Order** edges by non-decreasing length.
2. **Track** aspect ratio

$$l_S = \frac{|S| - A_{\min}}{\min_{e \in S}(|e|)}$$

for each segment.

3. **Merge** the segments S, S' on either side of an edge e if

$$|e| > \kappa \cdot \min(l_S, l'_S)$$

INTERACTIVE FINETUNING

The segmentation algorithm runs ins real-time and allows for the interactive manipulaion of the user parameters.

RESULTS

RGB Input used for FS04 [2] and SAM23 [4]. Our algorithm uses OLAT shadow-masks.

FS04 [2] is a graph-based segmentation algorithm using minimum spanning trees.

SAM23 [4] is a state-of-the-art learning-based algorithm that was trained on millions of images.

Our method achieves comparable results from shadow-masks without the need for training data.