Feature Preserving Artifact Removal from Dermoscopy Images

Howard Zhou[a], Mei Chen[b], Richard Gass[b], James M. Rehg[a]

Laura Ferris[c], Jonhan Ho[c], Laura Drogowski[c]

[a]School of Interactive Computing, Georgia Tech, 85 5th Street NW Atlanta, GA 30332, USA
[b]Intel Research Pittsburgh, 4720 Forbes Avenue, Suite 410 Pittsburgh, PA 15213, USA
[c]University of Pittsburgh Medical Center, 580 S. Aiken Avenue, PA 15232, USA

ABSTRACT

Dermoscopy, also called surface microscopy, is a non-invasive imaging procedure developed for early screening of skin cancers. With recent advances in skin imaging technologies and development of new image processing techniques, there has been a significant increase of interest in computer-aided diagnosis of pigmented skin lesions from dermoscopy images. Such diagnosis requires the identification of over one hundred cutaneous morphological features. However, computer procedures designed for extracting and classifying these intricate features can be distracted by the presence of artifacts like hair, ruler markings, and air bubbles. Therefore, reliable artifact removal is an important pre-processing step for improving the performance of computer-aided dermoscopy diagnosis. In this paper, we present a new scheme that automatically detects and removes hairs and ruler markings from dermoscopy images. Moreover, our method also addresses the issue of preserving morphological features during the artifact removal process. The key component of our methods include explicit curvilinear structure detection and modeling, as well as feature guided exemplar-based inpainting. We experiment on a number of dermoscopy datasets and demonstrate that our method produces superior results compared to existing artifact removal procedures.

Keywords: dermoscopy, artifact removal, image restoration and enhancement, skin cancer, surface microscopy

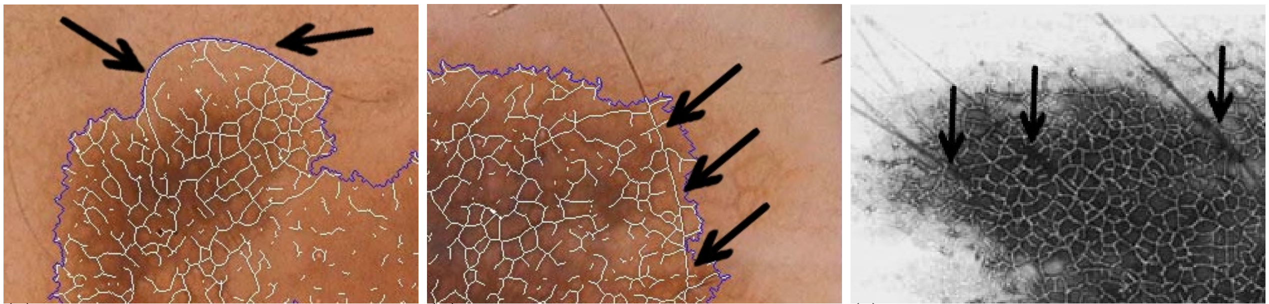
Presentation: Oral preferred, but poster acceptable.

1. PURPOSE

Dermoscopy is a non-invasive imaging procedure developed for early screening of skin cancers. It involves using an incident light magnification system, i.e. a dermatoscope, to examine skin lesions. Often oil is applied at the skin-microscope interface before the examination. The use of oil allows underlying morphological features to show through the epidermis. When capturing dermoscopy images for computer-aided diagnosis, the doctors mount cameras on the back of dermatoscopes and take pictures when they exam the patients. A typical examining session only lasts several minutes. As a result of the time constraint, three common artifacts, hairs, air bubbles, and dermatoscope ruler markings often appear in the acquired images. The presence of these artifacts can interfere with many analytic procedures required for computer-aided diagnosis as illustrated by Figure 1. In the first example (Figure 1(a)), the segmentation algorithm presented in Grana et al.[?] mistakes a piece of hair (indicated by the arrows) as the segmentation boundary. In the next image (Figure 1(b)), the hair at the top of the image confuses the same network analysis procedure[?] and masquerades as a part of the pigmented network. Similarly in Figure 1(c), several hairs break the network pattern extracted by a similar procedure developed by Fleming et al.[?] Therefore, successful removal of these artifacts is an important prerequisite for accurate computed-aided diagnosis of pigmented skin lesions.

Previous works in artifact detection and removal from dermoscopy images include works published by Fleming et al.[?] and Schmid et al.[?] In Fleming et al.[?]'s, the authors developed an automatic curvilinear structure detection and tracing algorithm to isolate the hairs, but they did not propose a method to remove the artifacts. On the

Further author information: (Send correspondence to Howard Zhou)
Howard Zhou: E-mail: howardz@cc.gatech.edu, Telephone: 1 404 385 4228



(a) Example of hair affecting lesion segmentation (image courtesy of Grana et al.)
(b) Example of hair masquerading as network patterns (image courtesy of Grana et al.)
(c) Example of hair interfere with network pattern extraction (image courtesy of Fleming et al.)

Figure 1. Artifacts interfere with computer procedures designed for extracting diagnostic features.

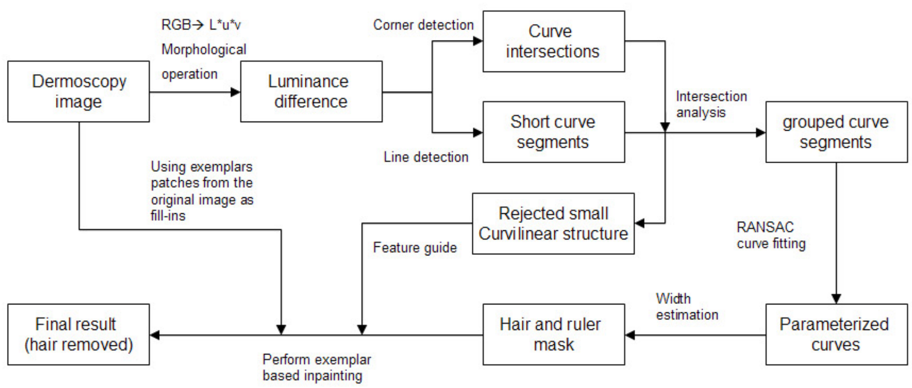


Figure 2. A flowchart describing the work flow of our artifact detection and removal scheme.

other hand, Schmid et al.[?] handles both detection and removal tasks using global morphological operations. Our work also focuses on both artifact detection and removal. We start with curvilinear structure detection and curve fitting to reliably detect hair and ruler markings. We then replace the selected pixels using feature guided, exemplar-based inpainting, which preserves morphological features that are important to diagnosis. In the following sections, we explain the procedures in detail and demonstrate that our method produces visually superior results in comparison with existing techniques.

2. METHODS

Figure 2 shows the work flow of our scheme. We first generate a luminance difference image in the way described by by Schemid et al.[?] The dark thin curvilinear structures are enhanced in the process, We then apply Steger's line detection algorithm[?] at three different scales to extract line segments within a certain width range. Due to noise and the presence of morphological features. The line segments extracted tend to be broken. Moreover, hair intersections, especially those near parallel ones, break line segments in a number of ways. We develop an intersection analysis to handle line grouping at intersection points. After detecting intersection points using Harris corner detector,[?] we exam each intersection point against a list of 13 common configurations. We then reassign the intersecting line segments into their respective line groups. Once all intersection points are handled, we group all the curve segments according to their positions, directions, and curvatures.

When the total length of a group of curve segments exceeds a preset threshold, our algorithm attempts to fit a cubic-spline to the group using RANSAC algorithm.[?] If such a model is accepted, we extrapolate the spline and search for curve segments belonging to the same spline but were separated by a wide gap in the previous stage. When all the long curves are parameterized, we estimate the width of them, and create an artifact mask using the curve parameters. The remaining short segments are rejected as non-artifacts. However, they are not discarded since they play an important role in the next procedure, feature guided exemplar-based hair removal.

Schemid et al.'s algorithm remove hairs by filling in the removed pixel with a value interpolating the pixel's surroundings. Instead, we search for patches (5×5 patches are used in our experiments) that match the pixel's surroundings in terms of both appearance (SSD) and features. The feature matching process is guided by the small curvilinear structures rejected during curve fitting. The more the curvilinear structures of the candidate patch align with those at the boundary of the region to be filled, the higher the matching score is. By the same spirit, our algorithm selects pixels to be filled in the order determined by features as well. The candidate sites are ranked according to the number of non-artifact pixels and a score indicating the strength of features present in the region to be filled. This way, patches with strong constraints are visited first and feature coherence are better preserved. This greedy algorithm like patch placement order is inspired by Criminisi's inpainting work.[?] our procedure stops when all of the removed pixels are filled.

3. RESULTS

We tested our algorithms on a data set of 460 dermoscopy images. These images are of various qualities ranging from high resolution (2200×1800) raw images to low resolution (480×360) web quality JPEGs. About one fifth of the images have artifacts. Our algorithms automatically detects these visible artifacts and removes them. Figure **??** shows a side-by-side comparison between the artifacts detection and removal results generated by Schemid et al.'s and our method, respectively. Notice that in Schemid et al.'s hair detection result (Figure **??**), although most of the pixels associated with hairs or ruler markings are picked up, a few non-artifact pixels are falsely selected as well due to their dark appearance. We point out that these false detections cannot be avoided by lowering the threshold, because the colors of the skin pigments are almost identical to the hairs. In fact, With the current threshold, some of the hair pixels are already missing (pointed out by an arrow in Figure **??**. With explicit hair shape modelling, our algorithm successfully detects the hair pixels and rejects dark skin pigments. Figure **??** and **??** show artifacts removal results generated by Schemid et al.'s algorithm and ours, respectively. While most of the noticeable hair pixels are removed from both images, the result generated by Schemid et al.'s algorithm has a noticeable blurred appearance at many removed pixel sites. This is due to the interpolation nature of their algorithm. The image generated by our method is free of such artifacts. Upon closer examination of both results (Figure **??** and **??**) and the same portion of the original image (Figure **??**), The difference is visible, our algorithm produces results that better preserve the appearance of the original feature.

4. NEW OR BREAKTHROUGH WORK TO BE PRESENTED

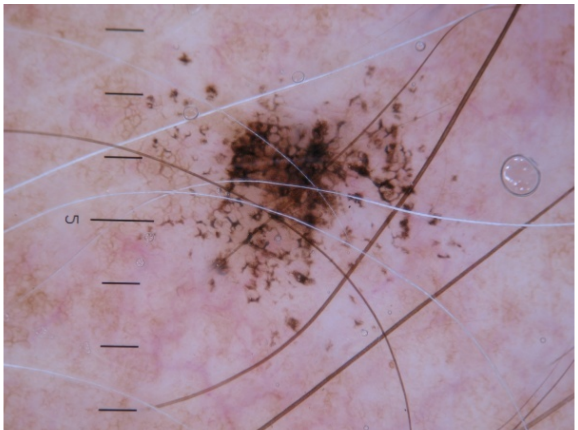
To the best of our knowledge, our algorithm is the first to address the issue of preserving diagnostic features during artifact removal in dermoscopy images. Moreover, with explicit modelling of intersecting linear structures, our algorithm is more effective at line tracing than existing graph search type of procedures.

5. CONCLUSIONS

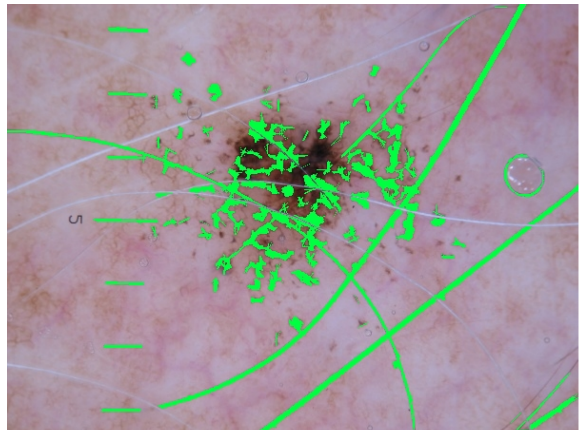
Artifact removal is an important pre-processing step for computer aided diagnosis of pigmented skin lesions from dermoscopy images. In this paper, we present a novel artifact detection and removal scheme. We achieve automatic hair and ruler marking detection using curvilinear structure analysis, and we perform explicit curve fitting to increase the robustness of our detection algorithm. After the artifact pixels are selected, we replace them using feature guided, exemplar-based inpainting. This allows our method to better preserve morphological features that are important to diagnosis. We tested our algorithms on a data set of 460 dermscopy images and the results are promising; our method produces visually superior restoration in comparison with previous methods.

6. PUBLICATION

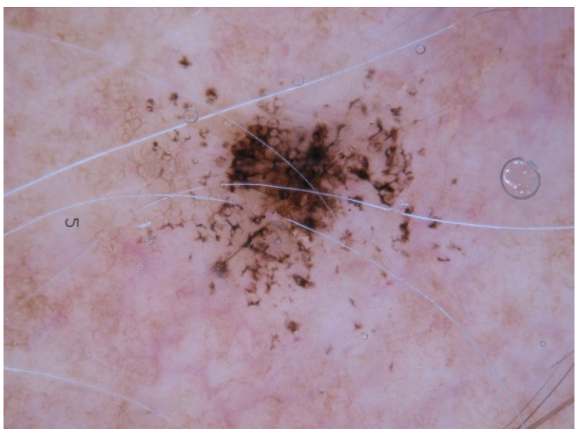
This work has not been submitted for publication nor presented elsewhere.



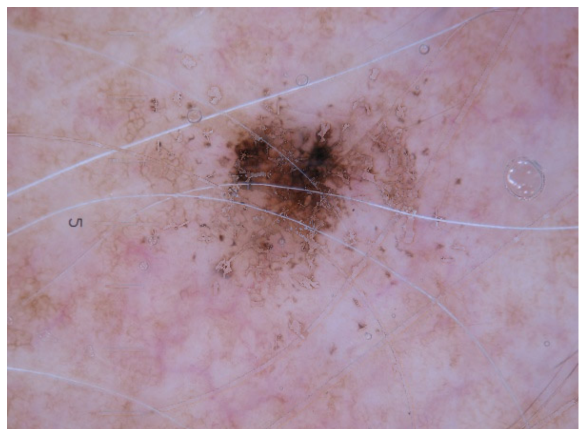
(a) Original dermoscopy image



(b) Hair detection result using Schemid's approach

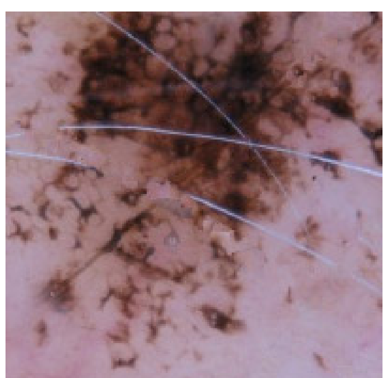


(c) Hair removal result using our method

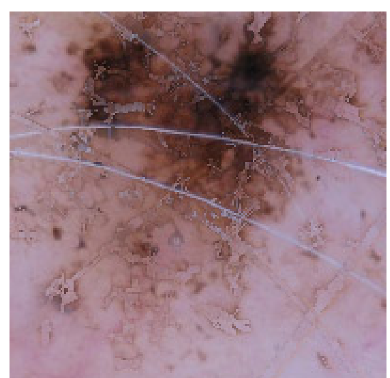


(d) Hair removal result using Schemid et al.'s method

(e) Close-up view of Schemid et al.'s result (**??**)



(f) Close-up view of our result (**??**)



(g) Close-up view of the original image (**??**)

Figure 3. A side-by-side comparison between the results obtained using ours algorithm and Schemid et al.'s algorithm.

REFERENCES

1. C. Grana, R. Cucchiara, G. Pellacani, and S. Seidenari, "Line detection and texture characterization of network patterns," in *Proc. of Intl. Conf. on Pattern Recognition (ICPR)*, pp. 275–278, IEEE Computer Society, (Washington, DC, USA), 2006.
2. M. Fleming, C. Steger, A. B. Cognetta, and J. Zhang, "Analysis of the network pattern in dermatoscopic images," *Skin Research and Technology* **??**(5), pp. 42–48, 1999.
3. M. Fleming, C. Steger, J. Zhang, J. Gao, A. Cognetta, I. Pollak, and C. Dyer, "Techniques for a structural analysis of dermatoscopic imagery," *Computerized Medical Imaging and Graphics* **22**(5), pp. 375–389, 1998.
4. P. Schmid-Saugeona, J. Guillodb, and J.-P. Thiran, "Towards a computer-aided diagnosis system for pigmented skin lesions," *Computerized Medical Imaging and Graphics* **27**, pp. 65–78, 2003.
5. C. Steger, "An unbiased detector of curvilinear structures," *IEEE Trans. Pattern Anal. Machine Intell.* **20**(2), pp. 113–125, 1998.
6. C. Harris and M. Stephens, "A combined corner and edge detector," in *Proceedings of the 4th Alvey Vision Conference*, pp. 147–151, 1988.
7. M. A. Fischler and R. C. Bolles, "Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography," pp. 726–740, 1987.
8. A. Criminisi, P. Pérez, and K. Toyama, "Object removal by exemplar-based inpainting," in *CVPR*, **2**, pp. 721–728, (Madison, WI), June 2003.