Automatic Gap Restoration in 2D and 3D Digital Images

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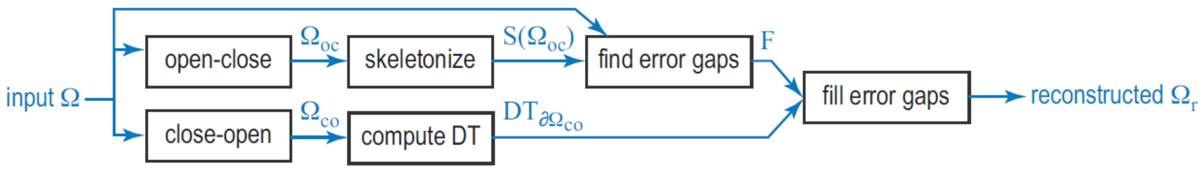
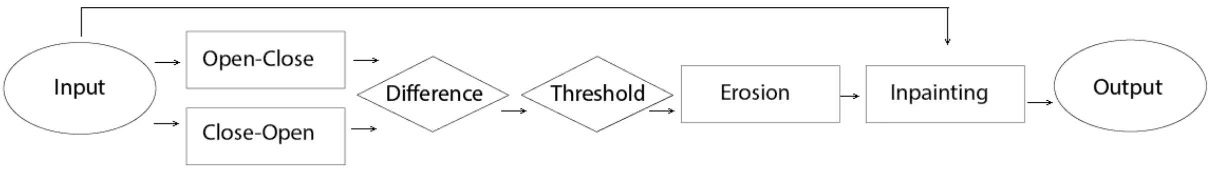
Many methods exist for removing defects such as gaps, cracks, and disconnections from digital shapes. However, most such methods have several limitations, such as removing both erroneous and important shape details, or requiring non-trivial effort from the end user in the form of manual delineation or parameter settings. We propose a technique for removing defects such as internal gaps and cracks from 2D and 3D digital shapes. For this, we first classify gaps as boundary detail (to be preserved) and interior errors (to be removed), based on a heuristic that uses the gap position with respect to the medial axis of the simplified shape. Next, we remove error gaps using an efficient distance-based inpainting. We illustrate our method on segmentation and hair removal tasks for skin imaging, and compare our results with a number of relevant techniques in this area.

Our main approach uses morphological open-close filters and skeletonization to find gaps which are thin and penetrate deeply into the main object to be processed (see figures below). Such gaps, deemed to be defects, are next filled-in using a distance-transform based reconstruction (for binary images) or inpainting (for color images). In contrast, shallow gaps along the shape boundary (indentations) are kept untouched [SJT]. Figure 1 shows several results of our previous work for detecting and removing gaps on binary and color images that come together with a binary segmentation mask.



As noted above, this approach is limited to shapes coming along with a *binary* segmentation or mask (which is analyzed to find gaps to be removed next). We propose here to extend our gap-detection and restoration method to handle arbitrary grayscale and color images, in the *absence* of a binary segmentation that captures such gaps. To do this, we first find gaps present at any luminance or hue level by using the thresholded difference of the morphologically open-closed input image (computed per image channel) with the actual input image. Next, we restore such gaps using classical image inpainting [Tel]. The diagram below illustrates our new method's pipeline.



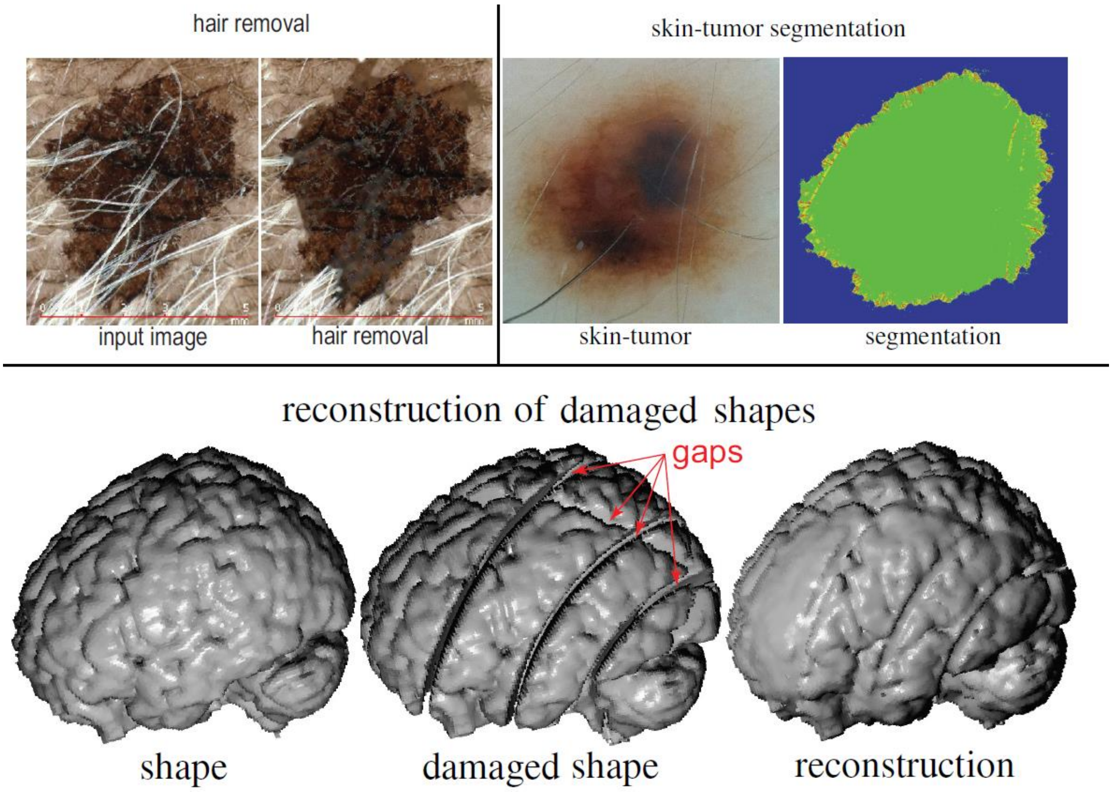


Figure 1.: Results of our gap-sensitive segmentation and restoration method for binary shapes.

Our generalized gap-detection-and-removal method can be efficiently and effectively used to automatically find and remove thin and elongated artifacts present in various types of images. Figure 2 shows examples of digital hair removal from dermoscopic images, prior to image-based analysis for skin-tumor diagnosis (a,b), removal of thin metal-probe implements from X-ray images used in cone-beam computer tomography (CBCT) images prior to 3D CT reconstruction (c,d), and automatic restoration of photographs damaged by folds (c,d) for the automation of missing persons recognition in police databases [FGB]. Our entire method can process images of resolutions up to 1024^2 pixels in a matter of seconds on a modern PC computer, making it attractive for many near-interactive use contexts in several applications. More information, including source code and examples, is available at http://www.cs.rug.nl/svcg/Shapes/HairRemoval.

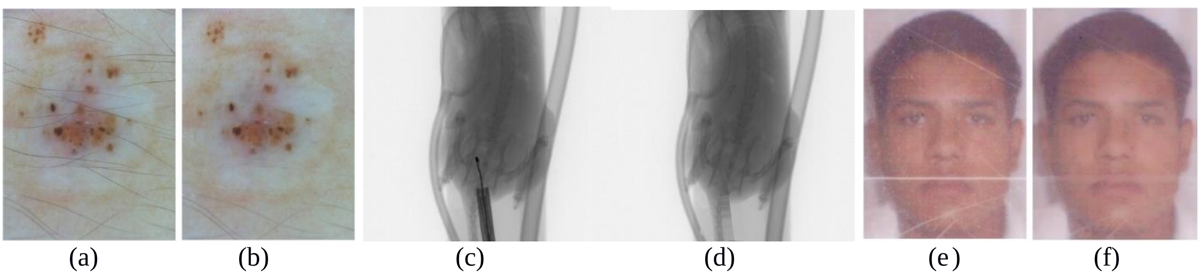


Figure 2.: Applications of our improved gap-filling method: (a-b) Digital hair removal in dermoscopy images; (c-d) Removal of wires and sheath bits in 2D X-ray images; (e-f) Artifacts removal in photographs.

References

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