Automated Segmentation Algorithm for Thermal Breast Images

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

Katharine Fergusson, Zainab Mahmood, Nada Kamona and Murray Loew
Department of Biomedical Engineering
George Washington University
Washington, D.C. USA

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OBJECTIVE

The objective of this study is to create an automated segmentation algorithm to isolate the breasts in infrared images of patients in order to limit the area for tumor search and reduce the time and effort needed for manual segmentation.

INTRODUCTION

Early detection of breast cancer is shown to be the key to higher survival rates for breast cancer patients. We are conducting a pilot study on breast cancer patients to investigate infrared thermography as a noninvasive adjunct to mammography for breast cancer screening. Thermography detects elevated skin temperatures that arise from increased blood flow because of the angiogenesis that accompanies tumor growth.

METHODS AND RESULTS

- Breast cancer patients and healthy volunteers were imaged for 15 minutes using an infrared camera (N2 Imaging Systems, Irvine, Calif.: 8-14μm, 640×480 pixels, 30mK sensitivity).
- Segmentation algorithm combining various edge detection techniques was developed using MATLAB
- Different segmentation algorithms were created for large and small breasts, which were differentiated visually via user input
- All images were 'cleaned' using morphological operations to remove small lines inside the breast region. These were due to the vasculature of the breasts and nipples.

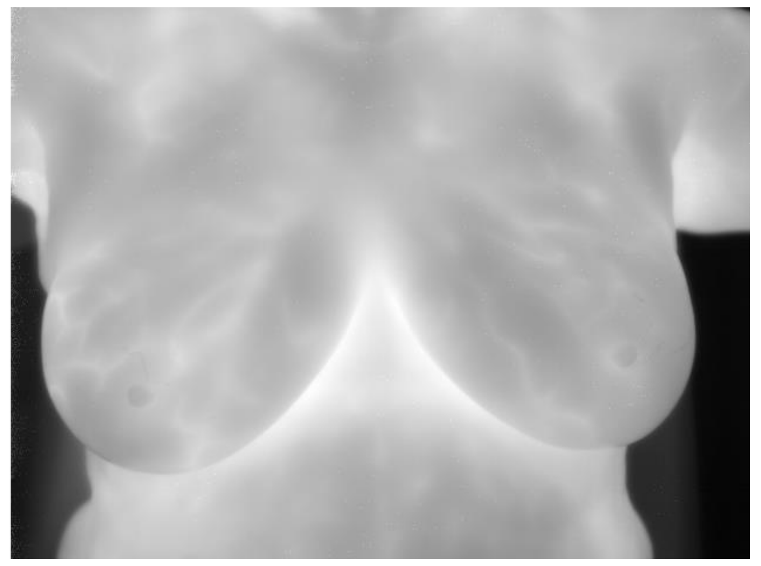


Figure 1. Original large breast thermal image

Figure 2. Original small breast thermal image

METHODS AND RESULTS (cont.)

Large Breast Segmentation

Figure 3. Canny edge detection

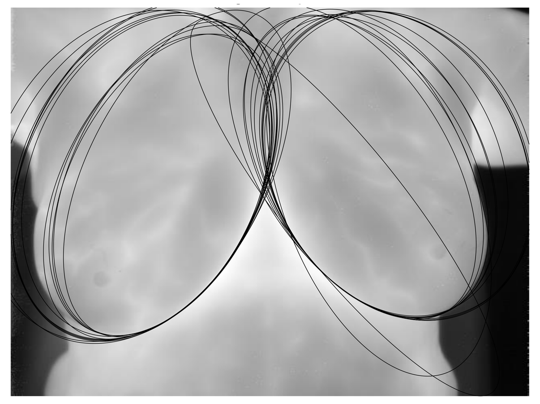


Figure 4. Ellipse detection

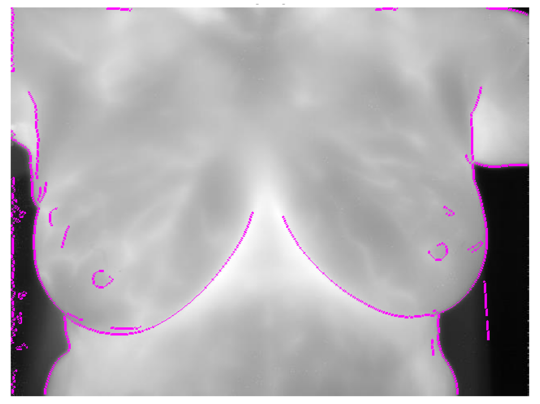


Figure 5. LoG edge detection

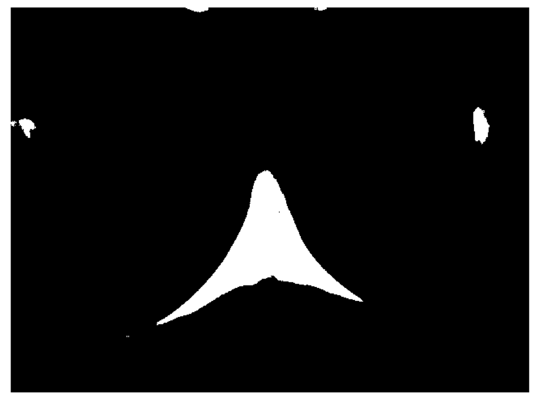


Figure 6. Hot pixel finder

Figure 7. Point system

1. Canny edge detection technique for strong and weak edges
2. Ellipse detection for lower inner breast boundaries
3. Laplacian of Gaussian ('LoG') edge detection for outer boundaries
4. Warmest 5% of pixels ("hot") for inner breast boundaries
5. Point system to weight different edge detection techniques

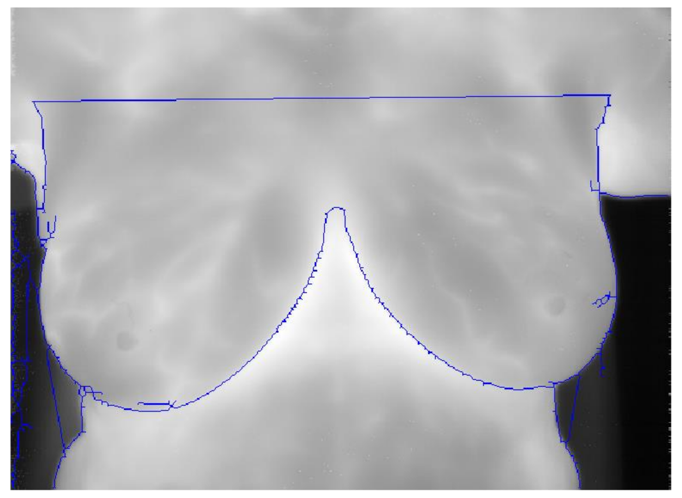


Figure 8. Final segmented image

Small Breast Segmentation

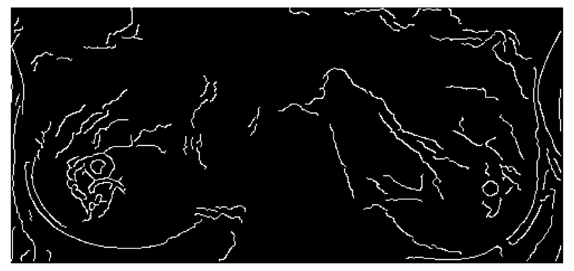


Figure 9. Canny edge detection

Figure 10. Hough transform

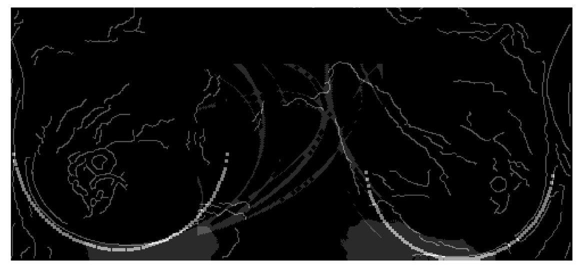


Figure 11. Point system

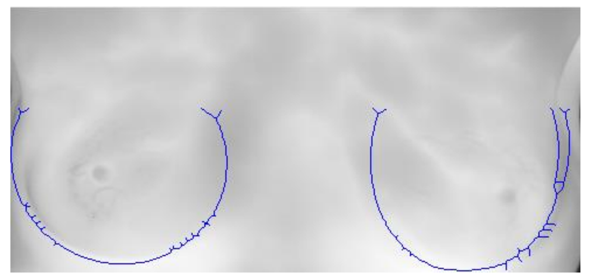


Figure 12. Second Hough transform

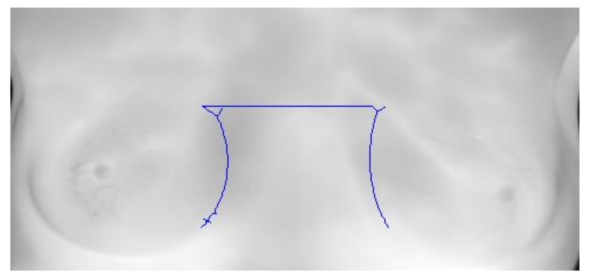


Figure 13. Inner connection

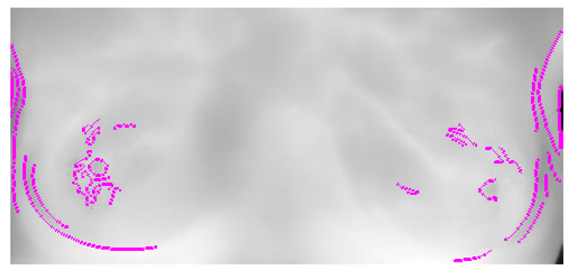


Figure 14. LoG edge detection

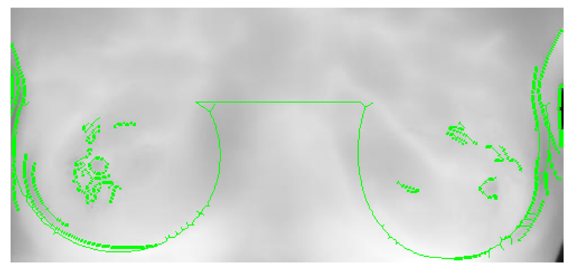


Figure 15. Final without cleaning

1. Canny edge detection technique for strong and weak edges
2. Hough transform to detect circular regions (exactly two)
3. Points systems to weight different edge detection techniques
4. Second Hough transform and deletion of upper one-third of pixels
5. Inner third of image found and connected
6. Laplacian of Gaussian ("LoG") edge detection for outer boundaries
7. Combined edge detection techniques without cleaning

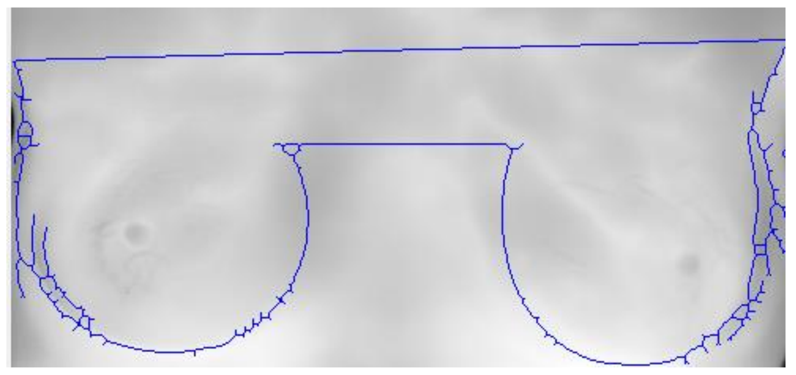


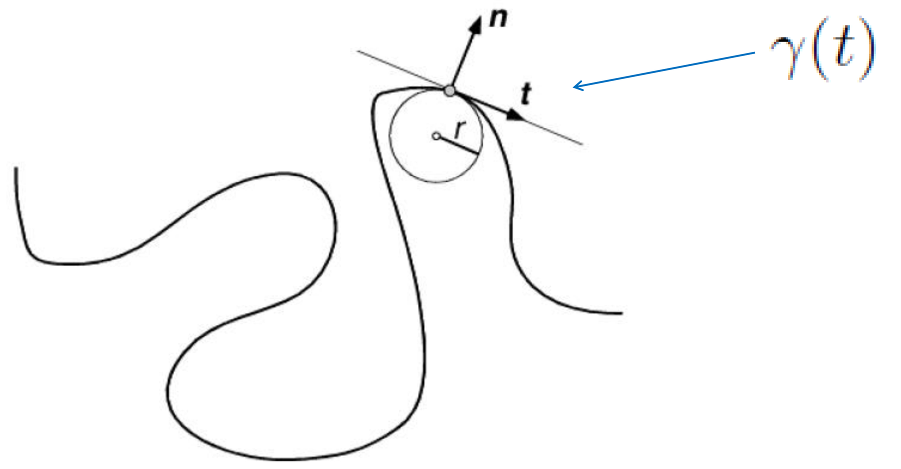
Figure 16. Final segmented image

DISCUSSION AND CONCLUSION

- Sixteen of the twenty-five cases were properly segmented using the created algorithm.
- The success of the algorithm depended on the breast size. Automatic segmentation of large breasts had an 80% (twelve of fourteen) success rate with cases properly segmented, compared to four of eleven cases of small-sized breasts.
- Extra checks, such as the point system, helped increase the accuracy of segmentation for small breasts.
- Five patient images were problematic due to interferences from the image background, such as belts, the chair the subjects sit on, or failure of the algorithm to detect the curves of interest. More work is underway to automatically correct for these inevitable clinical scenarios.

FUTURE RESEARCH

Future research focuses on calculating the curvature of the breast boundary using the rate of turn[1] in order to remove outliers. Assuming curvature changes slowly, calculated curvature values can be continued to get a better estimate of the inner breast boundaries.



$$\gamma(t) = (x(t), y(t)) = x(t)\mathbf{e}_1 + y(t)\mathbf{e}_2$$

$$\dot{\gamma}(t) = (\dot{x}, \dot{y}) = (\dot{x}(t), \dot{y}(t)) = \left(\frac{\mathrm{d}x(t)}{\mathrm{d}t}, \frac{\mathrm{d}y(t)}{\mathrm{d}t}\right)$$

$$\mathbf{t}(t) = \dot{\gamma}(t)/|\dot{\gamma}(t)|$$

$$\mathbf{t}(t) = (\cos\psi(t), \sin\psi(t)) = \cos\psi(t)\mathbf{e}_1 + \sin\psi(t)\mathbf{e}_2$$

$$\kappa(t) = \frac{\mathrm{d}\psi(t)}{\mathrm{d}L(t)} = \frac{\mathrm{d}\psi(t)}{\mathrm{d}l}$$

Figure 17. Curvature calculation using rate of turn (from [1])

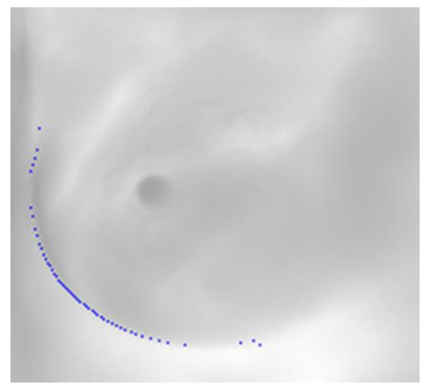


Figure 18. Single-pixel boundary

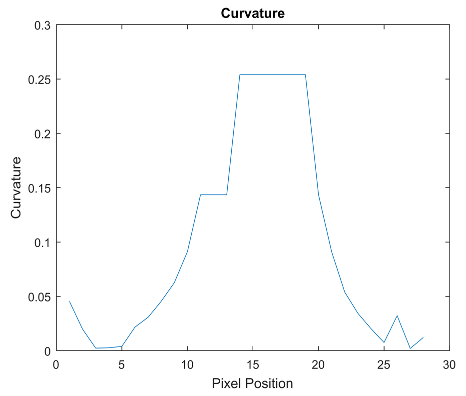


Figure 19. Curvature by pixel

REFERENCE

[1] Klette, R. and A. Rosenfeld. Digital Geometry: Geometric Methods for Digital Picture Analysis. San Francisco: Morgan Kaufmann, 2004, 1-5 pp.