Segmentation of B-Mode Ultrasound Images using SimpleITK API

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Purpose

- It has previously been established that changes in skin stiffness are associated with sclerotic skin diseases [1].
- ARFI and SWEI ultrasound imaging produce tissue displacement and shear waves to measure tissue elasticity. [2].
- To quantitatively determine the skin stiffness (Young's moduli) an accurate measurement of the skin thickness is needed.
- Accurate skin thickness measurements can be obtained through the segmentation of the B-mode tracking images. We seek to algorithmically segment the skin in these images at scale.
- Otsu's method has been previously used to segment B-mode images of the skin. This method often over segments the image. It is believed a CCRG method could out perform Otsu's due to the ability to place a seed region in the skin.

Medical Background

- Scleroderma is a group of conditions characterized by thick, sclerotic skin.
- 300,000 Americans suffer from varying forms of Scleroderma [3].
- Extremely difficult to diagnosis and monitor progression [3].
- Graft versus host disease (GvHD) is a condition that might occur after an allogeneic transplant [5].
- In GvHD, the donated bone marrow or peripheral blood stem cells view the recipient's body as foreign, and the donated cells/bone marrow attack the body [5].
- 50% of sclerotic skin cases are due to GvHD.

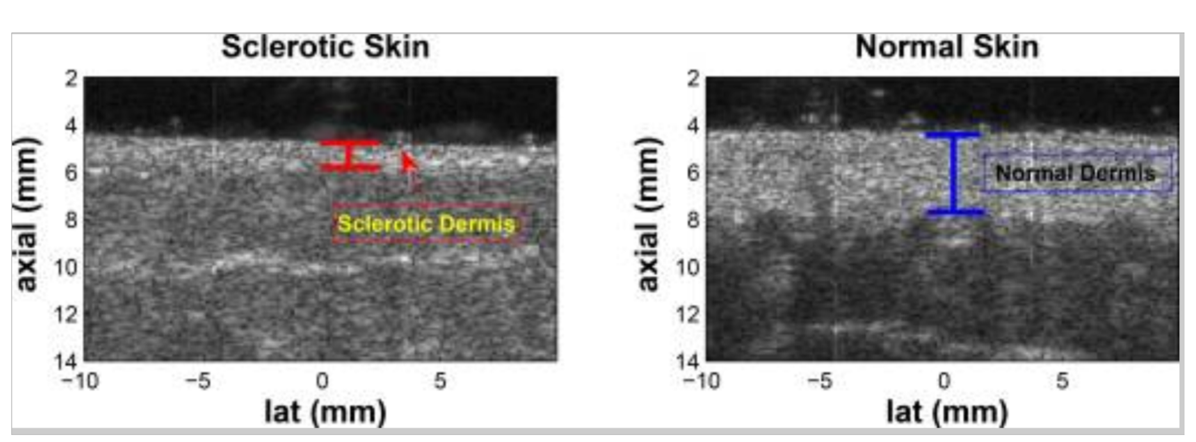

Figure 2: Ultrasound B-Mode images of sclerotic skin versus normal skin. Shows the distinct difference in skin thickness between sclerotic skin and normal skin [1].

Confidence-Connected Region Growth (CCRG)

- CCRG is a segmentation algorithm that grows a region based on the first order statistics of a user selected seed region [4].
- The algorithm first computes the mean and standard deviation of the seeded region [4].
- Pixels neighboring the seeded region are added to the region if their intensity value falls with the range determined by the mean and standard deviation of the seeded region. This continues until all possible pixels are added to the region [4].
- When all possible pixels are added the algorithm recomputes the mean and standard deviation of the new region. It then attempts to add all neighboring pixels that fit the new region statistics [4].
- The algorithm iterates for a user specified number of times or until no more pixels can be added to the region [4].

Key Parameters
1.) Seed Location
2.) Standard Deviation Multiplier
3.) Number of Iterations
4.) Initial Neighborhood Radius

Implementation

0.) All software is written in Python 3.7. The confidence-connected region growth algorithm is implemented using the SimpleITK API.

1.) Apply histogram equalization to the image prior to segmentation.

2.) Find the brightest row of pixels in the upper half of image

3.) Seed the image at brightest row with a user selected number of equally spaced seeds at the center of the image

4.) Run the confidence connect algorithm on the image.

5.) Perform hole filling on the image to fill any gaps in the segmentation.

6.) Add any pixels in or around the segmentation region that were too bright to be included.

7.) Determine the top and bottom boundaries of the skin
- Fit a linear function to both boundaries
- Remove outliers
- Fit a cubic function to remaining boundaries

8.) Subtract the central column bottom skin value from the top skin value to get the skin thickness

Results

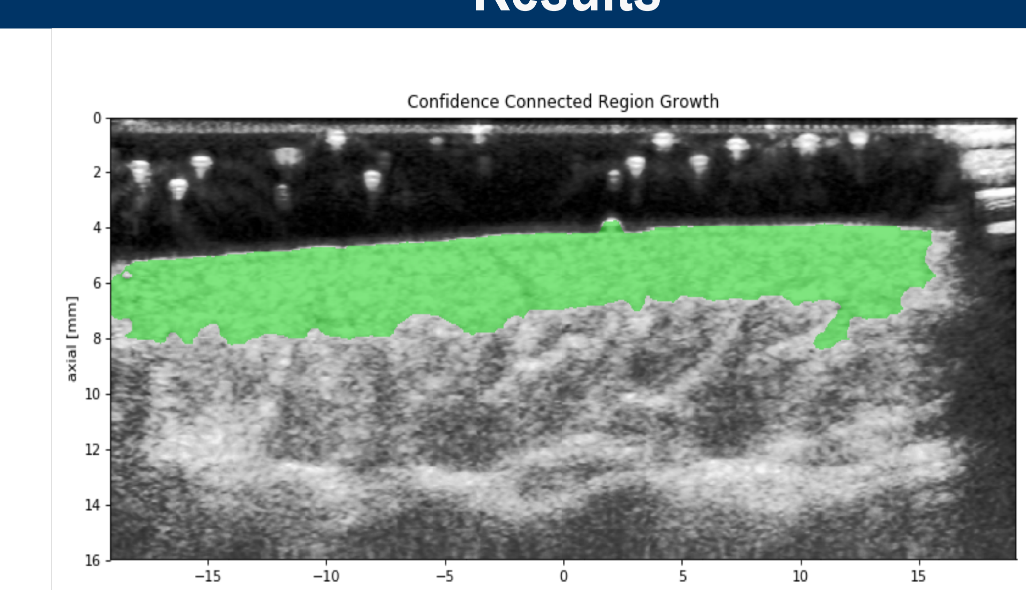

Figure 2: Example of a skin ultrasound image segmented by ITK's confidence connected region growth algorithm. The green portion of the image represents the segmented skin. The method produces clean and connected regions but is especially sensitive to image intensity changes.

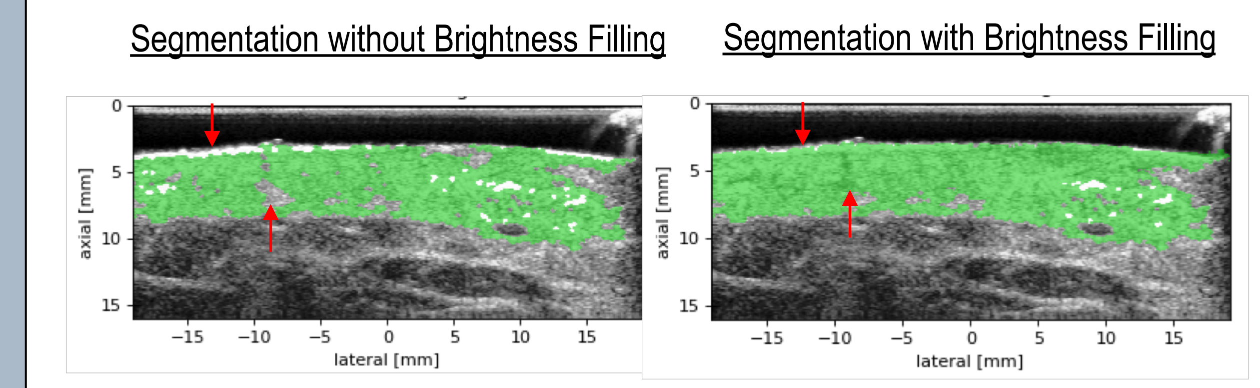

Figure 3: Example of a skin ultrasound image segmented by ITK's confidence connected region growth algorithm with and without brightness filling. The image on the left shows a common edge case where the epidermis is too bright to be segmented, leading to incorrect skin thickness measurements. The image on the right shows how brightness filling a segmentation can correct a common edge case. Red arrows denote areas where hole filling occurred.

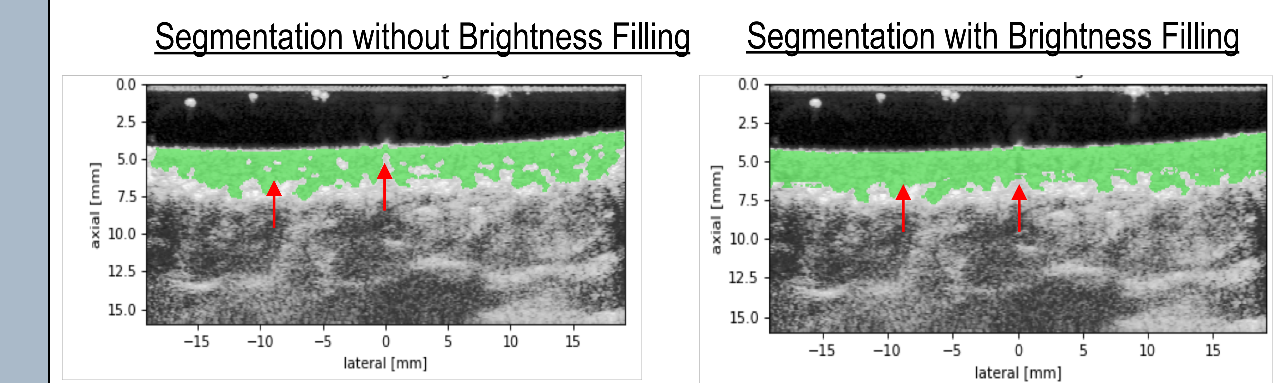

Figure 4: Example of a skin ultrasound image segmented by ITK's confidence connected region growth algorithm with and without brightness filling. The image on the left shows a common edge case where the epidermis is too bright to be segmented, leading to incorrect skin thickness measurements. The image on the right shows how brightness filling a segmentation can correct a common edge case. Red arrows denote areas where hole filling occurred.

Conclusion

- CCRG method produces high quality segmentations with smooth contours in optimal conditions. However, the method is very sensitive to imaging artifacts and aberrations.
- CCRG method performed worse when given images significantly different than the training data.
- A large portion of mis-segmentations by the CCRG method are due to distinct edge cases that include poor image contrast, bridging between the dermis & subcutaneous tissue, and overly bright regions.

Next Steps

- Experiment with changing the processing of the RF Ultrasound data to improve image contrast
- Explore methods for scrubbing away bridging from segmentation masks

References

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