FINE: Improving time and precision of segmentation techniques for vertebral compression fractures in MRI

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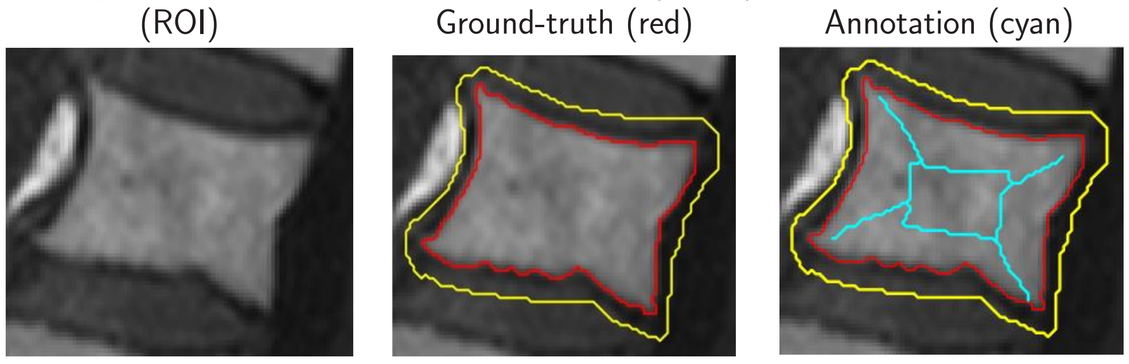
ABSTRACT

Lower back pain is often related to spinal diseases. In particular, Vertebral Compression Fractures (VCFs) can **impair mobility and compromise quality of life**. In a Computer-Aided Diagnosis (CAD) context, **the segmentation of VCFs is a challenging task** due to non-homogeneous intensities within the same vertebral body. Semiautomatic segmentation methods have been employed to cope with this challenge. However, these methods **require inside and outside annotation**, which is not practical when analyzing a more significant number of exams. **Aimed at minimizing the time spent on manual annotation**, we proposed **Fast INside Estimation (FINE)**, which **automatically estimates the inside seeds** based on the outside seeds. The experimental results with a representative dataset showed that **FINE does not demand manual inside annotation**, what the competitors methods do, and **achieve higher Recall and Dice Score**, on average, 97% and 96%, respectively. Higher Recall is particularly essential on features extraction and classification of VCFs. Therefore, **FINE speeds up the manual annotation process while allowing more accurate semiautomatic segmentation**.

PROPOSED METHOD

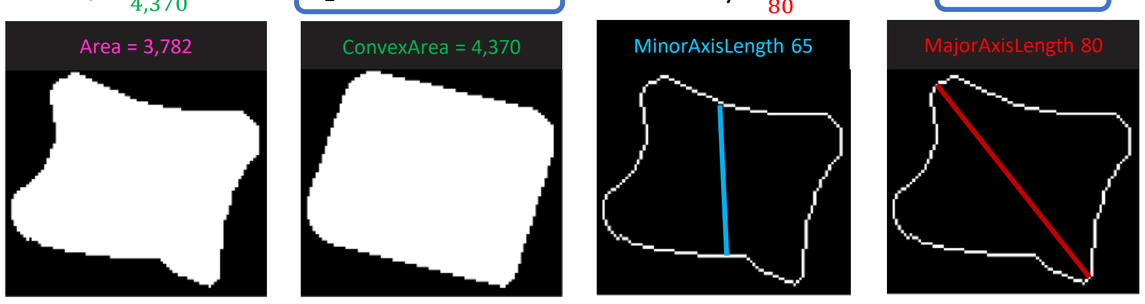
We automatically estimate the **inside annotation** based on the **outside annotation**.

Region of Interest (ROI) | Outside Annotation (yellow) Ground-truth (red) | Final Estimated Inside Annotation (cyan)



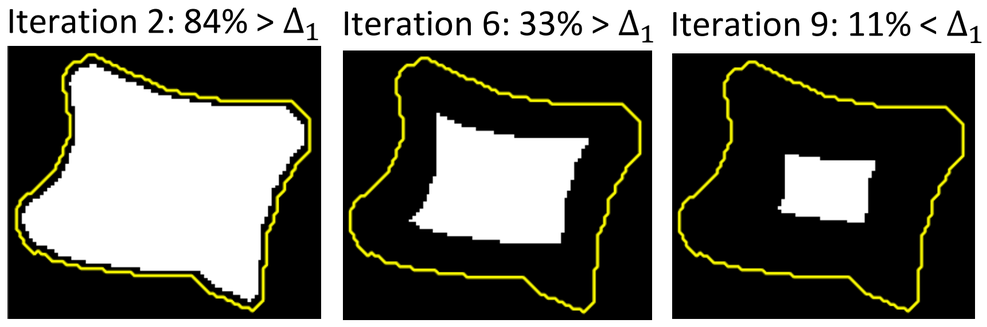
To do so, we fill the outside annotation and calculate the **Solidity** and **Eccentricity**. First, we calculate the thresholds $\mathbf{\Delta_1}$ (Solidity) and $\mathbf{\Delta_2}$ (Excentricity) as follows.

Solidity = $\frac{3{,}782}{4{,}370}$ = **0.86** $\Delta_1 = 1 - 0.86 = 14\%$ Eccentricity = $\frac{65}{80}$ = **0.81** $\Delta_2 = 81\%$



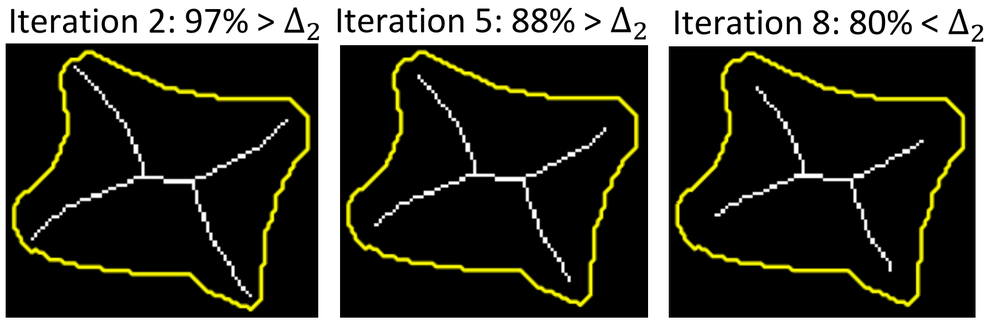
Then, we iteratively erode the region until it is not smaller than $\mathbf{\Delta_1}$ (Solidity):

Iteration 2: 84% > Δ_1 | Iteration 6: 33% > Δ_1 | Iteration 9: 11% < Δ_1



Next, we iteratively remove the skeleton end-points until $\mathbf{\Delta_2}$ threshold (Eccentricity):

Iteration 2: 97% > Δ_2 | Iteration 5: 88% > Δ_2 | Iteration 8: 80% < Δ_2



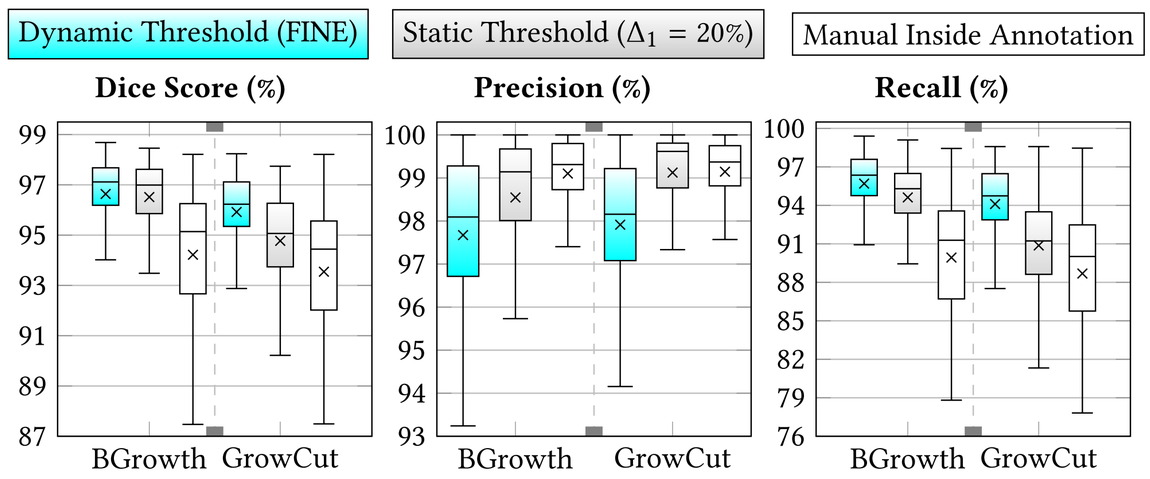
Finally, we join the resulting eroded region with the shrinked skeleton to make up the final inside annotation estimation.

METHODS

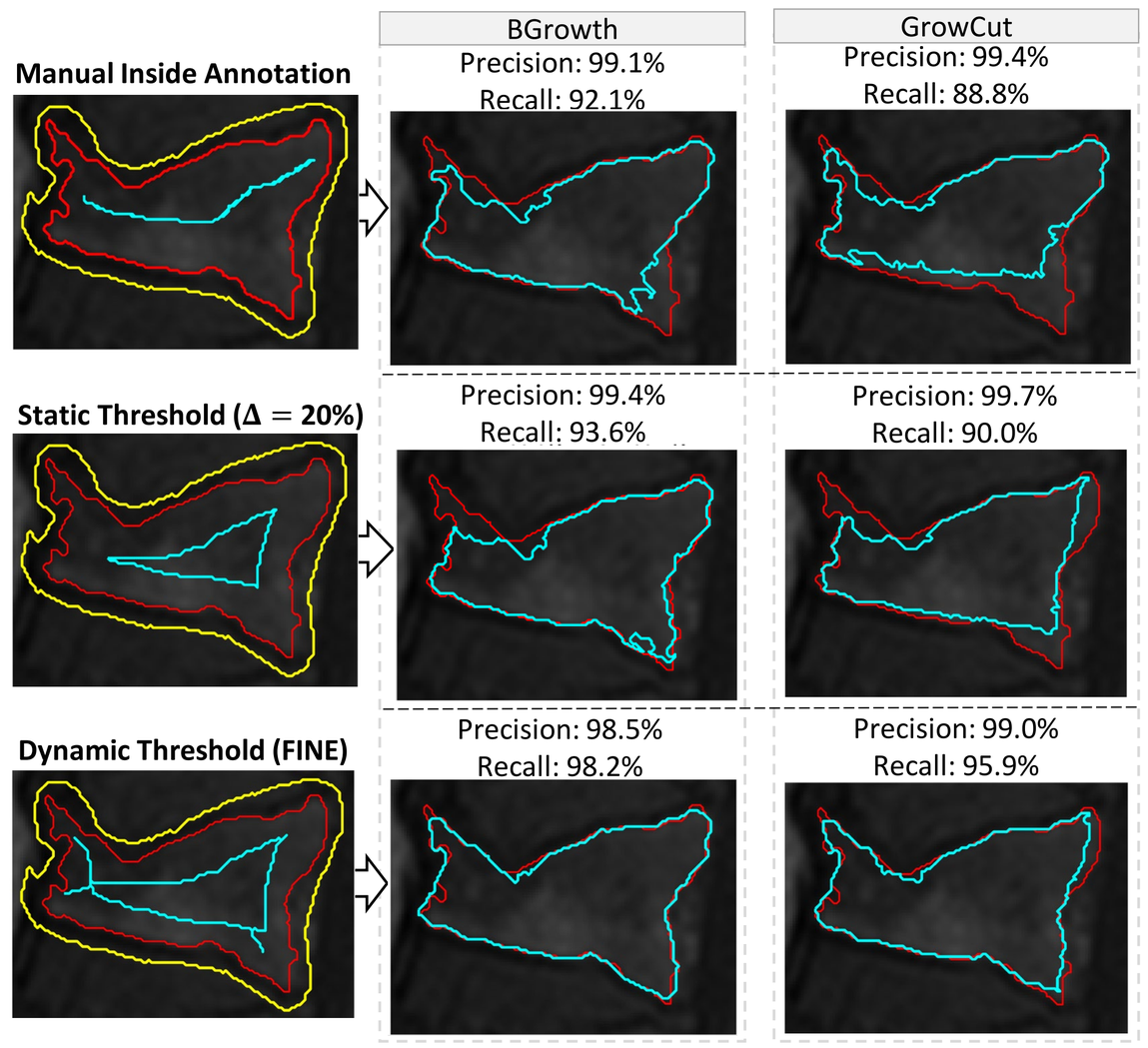
To validate FINE we have used a representative dataset of **lumbar vertebral bodies** with **89 healthy vertebral bodies** and **102 VCFs** (53 benign and 49 malignant) with corresponding ground-truth. To evaluate FINE we compared the results with **Balanced Growth** (**BGrowth**) Ramos et al. (2019), and **GrowCut** Vezhnevets & Konouchine (2005). We compare the results using well-known measures, such as **Precision**, **Recall**, **Dice-score**, and **Run-Time**. Moreover, we statistically analyze the results using the **Kolmogorov-Smirnov** normality test and the **Wilcoxon test**.

RESULTS

The overall data-distribution of the results is shown as follows.



In general, **FINE presented the best Recall** while the remaining methods do not segment the total region of the vertebral body, for this reason they achieved a higher precision. However, **FINE presented the best Dice Score**. To better illustrate this, we show the segmentation result for a malignant case as follows.



In the Wilcoxon test results, other methods outperformed FINE interms of Precision values. Nonetheless, we were able to improve the estimation of interior regions in all settings regarding Dice Score,Recall, and Run-Time measures

CONCLUSION

Semiautomatic segmentation methods have been employed to cope with the challenging task of Vertebral Compression Fractures (VCFs) segmentation. **Aimed at minimizing the time spent on manual annotation**, we proposed FINE, which automatically estimates the inside seeds based on the manual outside annotation. The experimental results showed that **the segmentation methods presented higher Recall and Dice Score** with FINE, on average, 97% and 96%, respectively. Higher recall values are particularly crucial for the classification of VCFs, since shape and texture features may be extracted with high certainty. **The obtained results emphasize that FINE can speed up the inside annotation of vertebral bodies and further improve the quality of the segmentation**.

REFERENCES

Ramos, J. S., Cazzolato, M. T., Faiçal, B. S., Nogueira-Barbosa, M. H., Traina Jr., C., & Traina, A. J. M. (2019, June 12). 3DBGrowth: volumetric vertebrae segmentation and reconstruction in magnetic resonance imaging. *Computer-Based Medical Systems (CBMS)*, 435-440.

Vezhnevets, V., & Konouchine, V. (2005, Nov). GrowCut - interactive multi-label N-D image segmentation by cellular automata. *International Conference on Computer Graphics and Vision (GraphiCon)*, *1*.

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