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Lumbar Spine L1-L5 Vertebral Position Localization and Spondylolisthesis Classification

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***Abstract*— Reviewing a significant quantity of x-ray findings can lead to doctor fatigue, which might subsequently result in incorrect diagnoses. In this study, artificial intelligence will be employed to develop tools that assist physicians in classifying Spondylolisthesis.**

***Clinical Relevance*— Numerous techniques and models are available for experimentation within this application. Nevertheless, the initial approach employed in this investigation yielded outcomes that exceeded expectations when compared to other competing methods in the field. As a result, there is potential for further enhancement in the results.**

I. Introduction

Spondylolisthesis is when lumbar spine vertebrae shift and identifying key points on each vertebra (L1-L5) is vital for classifying spondylolisthesis type based on slippage direction. This challenging task is crucial to the research. Lateral x-ray images include the sacrum, aiding L5 classification. Two models locate vertebrae. The last model uses EVA02 [1] (image classification model) to distinguish anterior and lateral images then using positions to classify spondylolisthesis.

The dataset includes front and side x-ray images with the lumbar spine, alongside precise vertebral positions and spondylolisthesis instances. These resources are provided by Burapha University.

II. Methods

The methodology will be separated into two-part, vertebral position and spondylolisthesis classification.

To pinpoint the four corner points on each spine, a chosen segmentation model is used. Labels are generated from the ground truth of these four points (x1, y1 to x4, y4), formatted following the YOLO standard. For side images with the Sacrum and its two points, two more points are created by incrementing the first two. Using the Ultralytics [2] library, the segmentation model is trained with 100 epochs for both side and frontal models. These models will predict images and identify corner points through position comparison.

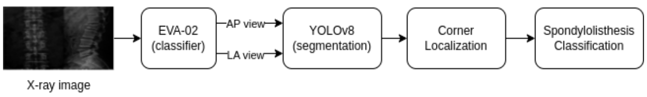

Figure 1. Methodology flow chart.

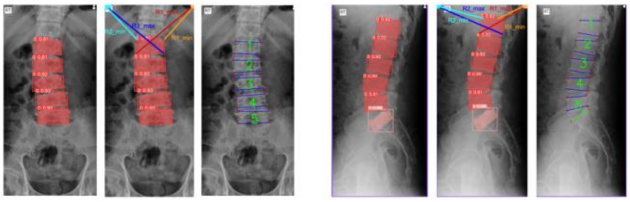

Figure 2. Corner generation.

Algorithm 1 An algorithm for Corner Localization

Require: Segmentation output (S)
Ensure: Best fitted corners $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4)$
Calculate the corners by identifying the points that result in the minimum or maximum distances from the image corners (top left and top right).
Examples,
$R2_{min} = \underset{(x_1,y_1)\in S}{\text{minimize}}(ax_1 + by_1)$ and $R2_{max} = \underset{(x_4,y_4)\in S}{\text{maximum}}(ax_4 + by_4)$
where $a = 0.5$, $b = 0.5$
while Area of bounding box from segmentation $\approx$ Area from corners **do**
Change the parameters (a, b) from the equation to minimize or maximize.
end while

Figure 3. Pseudo code for vertebral position

Spondylolisthesis classification employs two upper and two lower points from the lumbar spine. This computes slippage by determining line slope and calculating line intersection, using the distance between upper and lower point centers to measure the distance. Cases are determined by whether the upper line's center orientation exceeds a set threshold in relation to the lower line.

III. Results

In Corner Localization, Mean Absolute Error (MAE) measured the variance between the positions of the four corners in L1 – L5 and the ground truth, resulting in a MAE of 0.00016. In Spondylolisthesis Classification, F1 Score assessed class distinction error, yielding 0.7385.

IV. Discussion & Conclusion

This study's approach could improve by using "segment anything" techniques, transitioning from four reference points to actual masks to enhance segment label accuracy. Employing advanced models like RT-DETR or Yolo-NAS, known for higher mAP, could enhance detection precision. Integrating "segment anything" could effectively mask the spine, yielding better results.

References

[1] Y. Fang, Q. Sun, X. Wang, T. Huang, X. Wang, and Y. Cao, "Eva-02: A visual representation for neon genesis," arXiv preprint arXiv:2303.11331, 2023.
[2] G. Jocher, A. Chaurasia, and J. Qiu, "YOLO by Ultralytics," Jan. 2023.

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