# Fast scale-invariant lateral lumbar vertebrae detection and segmentation in X-ray images

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***Abstract***

Fully automatic localization of lumbar vertebrae from clinical X-ray images is very challenging due to the variation of X-ray quality, scale, contrast, number of visible vertebrae, etc. To overcome these challenges, we present a novel framework, where we accelerate a scale-invariant object detection method using Support Vector Machines (SVM) trained on Histogram of Oriented Gradients (HOG) features and segmenting a fine vertebra contour using Gradient Vector Flow (GVF) based snake model. Support Vector Machines trained on HOG features are now an object detection standard in many perception fields and have demonstrated good performance on medical images as well. However, the computational complexity and lack of robustness brought by rescaling the original images have prevented its applicability. The proposed multistage detection framework uses lower-level detection result to determine the re-scaling regions to reduce the region of interest, thereby decreasing the execution time. We further refine the detection result by segmenting the contour of vertebra using GVF snake, where we use edge detection techniques to increase the robustness of the GVF snake. Finally, we experimentally demonstrate the effectiveness of this framework using a large set of clinical X-ray images.

## Introduction

**Adult Spine Deformity (ASD)** affects the lives of a large population. Building spine model automatically is helpful for efficient diagnosis of ASD. In this work, we propose a novel detection and segmentation framework to accelerate this process and overcome the challenges brought by large variations in X-ray images. Fig. 1 shows the variation of the input images.

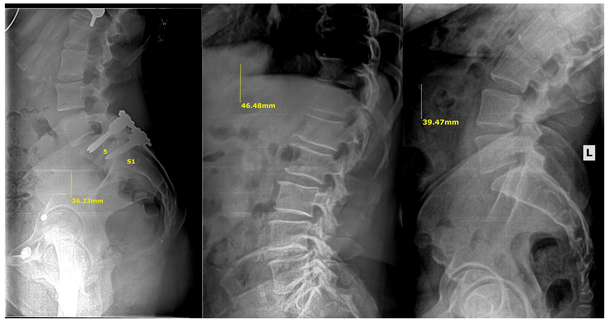


Fig. 1. Variations of lateral lumbar X-ray images. From these images we can see that the intensities vary considerably; the curvature of the spine differs; image contrast is low; and the number of visible vertebrae differs. These factors are some of the challenges for fully automatic vertebrae detection and segmentation.

## Method and Result

*A. Multi-stage Vertebrae Detection*

Our detection framework is based on SVM trained on HOG feature in a sliding window fashion. Fig. 2 illustrates the visual effect and Fig. 3 shows the proposed novel detection framework.

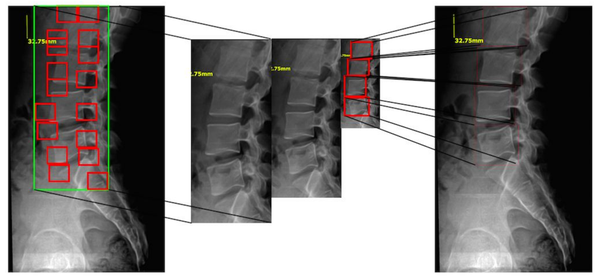

Fig. 2. Multi-stage detection. Image on the left illustrates the first stage of detection, using object parts as samples. Middle image illustrates how the rescaling has reduced to ROI, thus reducing classification time; and the image on the right shows the detection result added back to the original scale.

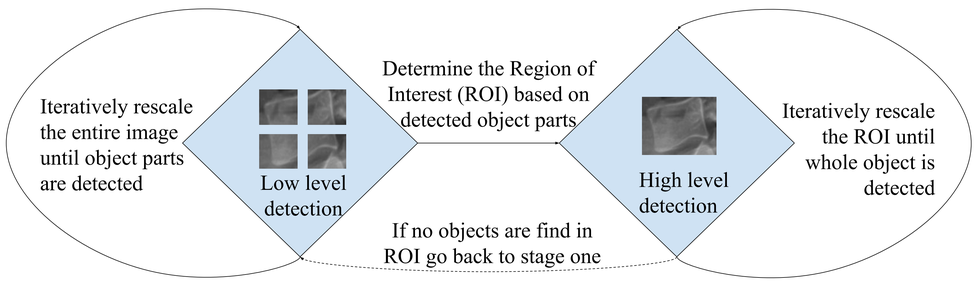


Fig. 3. Work-flow of our fast detection algorithm. First stage (on the left) iterate until object parts are detected and use the bounding box of the result as ROI. Second stage (on the right) uses full object detection.

*B. Vertebra Segmentation*

Segmentation is based on canny edge detection and GVF. Fig. 4 shows the results.

Fig. 4. Right image shows the edge detection result and left image shows the segmentation result.


*C. Execution Time Comparison*

To conduct our experiment, we used 30 clinical lateral lumbar X-ray images with varying parameters, in terms of number of visible vertebrae, intensities, noise level, etc. Table below shows the execution time comparison based on these images. Our true positive detection rate overall reached 75%.

| | Our method | Conventional method |
|---|---|---|
| AVG time per image (min) | **3.1** | 5.4 |
| AVG iteration number | 2.1 | 2.3 |

## Conclusions

In this work, we proposed a novel and fast scale-invariant object detection and segmentation framework for lateral lumbar vertebrae X-ray images. Our framework simply handles different scaling issues in images and reduced the execution time by using multistage detection. In the segmentation process, we use canny edge detector and Gradient Vector Flow (GVF) to achieve the fine contour of the vertebra.