

Advancements in Metastatic Spinal Angle Assessment: Clinical Application of a Novel 3D Vertebrae Detection Algorithm

Geoff Klein^{1,2}, Isaac Carreno^{5,6}, Joel Finkelstein^{4,5,6}, Arjun Sahgal^{1,3}, Jay Detsky³, Cari Whyne^{1,4}, Anne Martel^{1,2}, Michael Hardisty^{1,4}

¹Physical Sciences, ⁵Division of Spine Surgery, ⁶Orthopaedic Surgery, Sunnybrook Research Institute; Department of ²Medical Biophysics, ³Radiation Oncology, ⁴Surgery, University of Toronto

INTRODUCTION:

Traditional methodologies often come encumbered with constraints, fixating on predetermined regions, and offering visibility of a consistent number of vertebrae. Our model, conversely, prioritizes adaptability. Given that the focal point of evaluation is typically the tumour-bearing vertebra and factoring in the propensity of metastatic involvement to induce malalignment proximal to the disease locus, this flexibility emerges as a critical asset. Metastatic spinal pathologies present a multifaceted clinical challenge, particularly in the precise quantification of angulation for both kyphotic and scoliotic deformities. Within this context, Cobb angles, pivotal for assessing such deformities, are integral for determining appropriate therapeutic interventions. This investigation introduces an advanced algorithm, leveraging a 3D vertebrae detection model, to compute Cobb angles in the metastatic spine across both coronal and sagittal planes. The aim is to enhance the accuracy of Spinal Instability Neoplastic Score (SINS) assessments and thereby optimize therapeutic strategies.

METHODOLOGY:

This research employs a vertebral detection model which identifies vertebral body centroids, vertebra segmentations, and vertebral level classifications. For the precise computation of angles, the algorithm blends both spline and segmentation contour methods, Figure 1. Validation and testing of the model were conducted with data from Stereotactic Body Radiation Therapy (SBRT) treatment planning and subsequent follow-up scans.

RESULTS:

Empirical data underscore the algorithm's efficacy. Noteworthy performance metrics include a Mean Absolute Error (MAE) of 4.6° (95% CI, 3.8°-5.4°) for the coronal plane and 5.9° (95% CI, 5.0°-7.2°) for the sagittal plane. This mirrors or surpasses benchmarked standards set by existing models, underscoring the efficacy of our approach. The Symmetric Mean Average Percent Error (SMAPE) was quantified at 43.5% for the coronal plane and 20.6% for the sagittal plane. It should be highlighted that while SMAPE values for the coronal plane exceeded those documented in existing literature, its utility in this specific research milieu is mitigated due to its intrinsic property of inverse scaling with angle magnitude.

DISCUSSION:

The presented algorithm epitomizes state-of-the-art performance in the angle measurement of metastatic spinal structures. Traditional methodologies often come encumbered with constraints, fixating on predetermined regions and offering visibility of a consistent number of vertebrae. Our model, conversely, prioritizes adaptability. Given that the focal point of evaluation is typically the tumour-bearing vertebra and factoring in the propensity of metastatic involvement to induce malalignment proximal to the disease locus, this flexibility emerges as a critical asset. The use of SBRT radiation treatment planning and subsequent scans further emphasizes the algorithm's clinical potential in diverse clinical scenarios. While prior research efforts have predominantly fixated on 2D coronal or sagittal plane analyses, this algorithm supersedes such limitations, providing accurate multi-planar assessments.

CONCLUSION:

At its core, this research has pioneered a transformative, fully automated solution to measure Cobb angles in the metastatic spine across a multi-planar spectrum, leveraging a state-of-the-art 3D vertebrae detection paradigm. The precision and versatility exhibited by this tool are propitious for its imminent incorporation within the SINS framework for mechanical stability evaluations. Future research trajectories will delve into amalgamating this automated angle measurement protocol with other pertinent image features associated with fracture risk, aiming to seamlessly embed this solution within clinical workflows. Through such integration, the research endeavours to refine clinical decision-making paradigms, thereby championing the imperative of individualized therapeutic regimens.

SIGNIFICANCE/CLINICAL RELEVANCE:

The precise quantification of spinal angles in metastatic cases directly impacts clinical decision-making, enabling optimized therapeutic approaches, enhanced patient prognosis, and a stronger understanding of the underlying biomechanics for vertebral stability.

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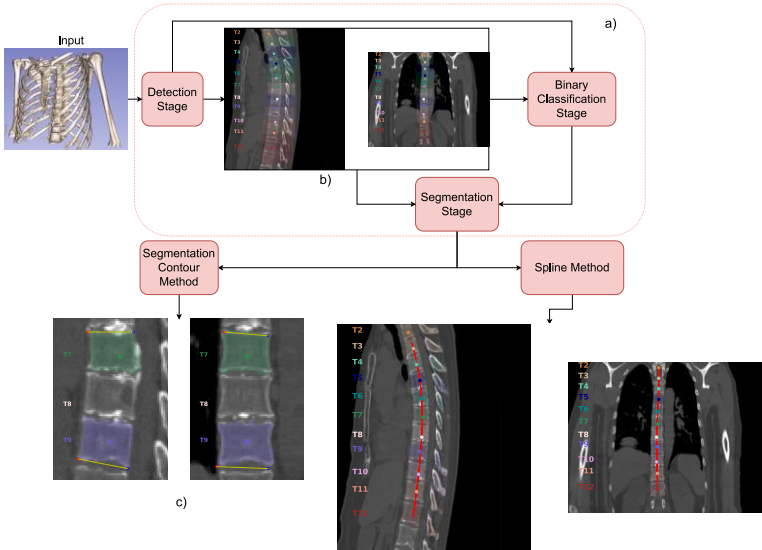


Figure 1: Workflow for angle measurements. A 3D CT scan (input) is fed into the detection model, a). Bounding boxes and centroids predictions are used to predict vertebra segmentations, b). Segmentations are used to calculate angles using the segmentation contour method, c), and the spline method, d).