2. Unified Evaluation Protocol

This study uses a consistent protocol: detection/instance segmentation use mAP (0.50-0.95 IoU, plus 0.50/0.75 and per-class results); mask quality uses Dice and 95th-percentile Hausdorff distance (by anatomy/level); level-wise labeling uses Top-1 accuracy/confusion matrix (vertebrae/discs separately). It follows COCO for detection.

Protocol details: patient-level splits (with IDs/seeds), specified preprocessing/augmentation, class imbalance solutions (report per-class/overall results), domain shift quantification (by vendor/T1-T2), and released metric scripts/model info for reproducibility.

3. Cross-domain generalization: sources and strategies

In multi-center lumbar spine MRI, domain shift stems from acquisition (vendor, T1/T2, resolution, etc.) and annotation (nomenclature/boundary inconsistencies). Results should be stratified by vendor/sequence/resolution, with harmonized terminology.

Mitigation: two-stage cascade (high-recall detector + high-fidelity segmenter), topology-aware postprocessing, class resampling/loss weighting (rare levels), test-time augmentation. These boost cross-domain stability under unified reporting.

This study proposes a unified lumbar spine MRI evaluation framework using public multi-center data, employing mAP (IoU 0,50–0,95) for detection/segmentation, Dice and 95 % Hausdorff distance for mask quality, and level accuracy within ROIs to quantify domain shifts and enhance reproducibility. Future work should implement patient-level splits, stratified reporting by vendor/sequence, and a two-stage cascade with topology-constrained postprocessing, augmented by resampling for rare levels and test-time augmentation. Subsequent studies should target per-class mAP $\geq$ 0,80 and level accuracy $\geq$ 97 % using representative models to ensure clinically applicable results.

R e f e r e n c e s

1. SPIDER – URL: https://zenodo.org/records/10159290, VB/IVD DB: https://osf.io/-qx5rt/ (date of access: 11.10.2025).
2. Kanstantsin Kurachka, Ren Huanhai. Intelligent System for Analyzing MRI Images to Find the Main Elements of the Human Spine // 2025 Open Semantic Technologies for Intelligent Systems (OSTIS-2025). – С. 361–366.
3. Kurachka Kanstantsin, Ren Huanhai, Wang Xuemei .Comparative Analysis of Deep Learning Models for Lumbar Vertebrae Segmentation in MRI Image // 2025 Pattern Recongnition And Information Processing (PRIP 2025). – С. 176–179.

RESEARCH ON THE METHOD OF HUMAN LUMBAR SPINE MODEL RECONSTRUCTION BASED ON PUBLIC DATASETS

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This paper aims to describe a standardized reconstruction process for computational biomechanical models of the human lumbar spine based on publicly available CT datasets. The process begins with the geometric and topological information of the publicly available datasets and proceeds through three sequential stages: data preprocessing, geometric model reconstruction, and biomechanical modeling and simulation, ultimately generating a patient-specific model suitable for simulation analysis. This paper systematically discusses the fundamental role of publicly available datasets as data sources in the reconstruction process, and proposes a series of methods for reconstructing computational models of the human lumbar spine. This work provides a clear technical path for the reproducible construction of computational lumbar spine models.

Keywords: model reconstruction, computational biomechanics, public dataset, process, parameterization, validation.

ИССЛЕДОВАНИЕ МЕТОДА РЕКОНСТРУКЦИИ 3D-МОДЕЛИ ПОЯСНИЧНОГО ОТДЕЛА ПОЗВОНОЧНИКА ЧЕЛОВЕКА НА ОСНОВЕ ОБЩЕДОСТУПНЫХ НАБОРОВ ДАННЫХ

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Целью данной работы является формализация стандартизированного процесса реконструкции для вычислительных биомеханических моделей поясничного отдела позвоночника человека на основе общедоступных наборов данных КТ. Процесс начинается с формирования геометрической и топологической информации общедоступных наборов данных и проходит через три последовательных этапа: предварительную обработку данных, реконструкцию геометрической модели и биомеханическое моделирование и симуляцию, в конечном итоге создавая специфичную для пациента модель, пригодную для симуляционного анализа. В данной работе систематически обсуждается фундаментальная роль общедоступных наборов данных как источников данных в процессе реконструкции и предлагается ряд методов реконструкции вычислительных моделей поясничного отдела позвоночника человека. Данная работа предоставляет четкий технический путь для воспроизводимого построения вычислительных моделей поясничного отдела позвоночника.

Ключевые слова: реконструкция модели, вычислительная биомеханика, публичный набор данных, процесс, параметризация; проверка.

In the field of computational biomechanics, constructing a high-fidelity human lumbar spine model is a prerequisite for any quantitative analysis. However, traditional model reconstruction processes often rely on in-house, non-public data and methods, limiting their reproducibility and comparability [1]. The recent release of publicly available CT datasets with detailed annotations (such as VerSe and CTSpine1K) has provided an opportunity to address this issue. They provide standardized, auditable input for model reconstruction.

The current research gap is the lack of a clear, end-to-end standardized reconstruction process to clearly guide how to systematically generate a model that can be used for biomechanical calculations from these publicly available data. The core contribution of this paper is that we define and validate a hierarchical model reconstruction process, and deeply analyze how the public datasets serve as the foundation of this process, how the core reconstruction technology (parameterization) plays a role, and how the hierarchical validation metrics ensure the quality of the final model [2].

Public datasets are the standardized cornerstone of the framework. Our selection strategy focuses on large, publicly available CT datasets with clear vertebral level annotations. These datasets play an indispensable role in this framework, and their core value lies in providing a common starting point for the modeling process.

Standardized source for geometry and annotation provides a stable, unified source of geometry and annotation for patient-specific modeling. Directly using this pre-annotated data bypasses the bias introduced by varying segmentation protocols across institutions and ensures that all models are constructed using the same anatomical definitions [1–3].

And the large, multi-center sample allows us to stress-test the entire automated pipeline, from segmentation to simulation. By running the pipeline on data from different devices, pathologies, and voxel sizes, we can assess its robustness and ensure that the framework is not limited to a specific type of scan data.

Proposed in this study for reconstructing the computational model of the human lumbar spine is a sequentially executed, modular pipeline.

Data processing stage: Input the original CT image and preprocess the data, such as grayscale normalization, which can standardize the grayscale value of the CT image to ensure the consistency of data under different equipment and different scanning conditions.

1. Geometric model reconstruction: During the model reconstruction phase, an automated segmentation algorithm (such as a deep learning model) is used to separate each vertebra from the CT image. Surface mesh reconstruction is then performed, converting the segmented vertebral regions into a 3D surface mesh model (such as in STL format). Simultaneously, the generated mesh is smoothed to remove noise and irregularities, improving model quality. Finally, a 3D spinal model is obtained through segmentation.

2. Based on the generated geometric model, a biomechanical model is established, combined with the Gibbon toolbox Using tools such as MATLAB, we developed an automated program to implement lumbar spine finite element meshing, load path and nucleus pulposus area delineation, and the setting of material properties and boundary conditions. We also designed a user interface for the automated lumbar spine model processing program, enabling users to easily load, process, and export lumbar spine model data.

This article details a human lumbar spine reconstruction process based on a public dataset. Parameterization is the core technical component of the reconstruction, while the public dataset serves as the starting point and quality assurance for the process. These components are closely interwoven with this core component, forming a complete, reliable, and auditable model reconstruction solution.

References

1. Kurachka K. S., Tsalka I. M. Vertebrae detection in X-ray images based on deep convolutional neural networks. 2017 IEEE 14th International Scientific Conference on Informatics. – IEEE, 2017, pp. 194–196.
2. Kurachka Kanstantsin, Ren Huanhai, Wang Xuemei .Comparative Analysis of Deep Learning Models for Lumbar Vertebrae Segmentation in MRI Images. 2025 Pattern Recongnition And Information Processing(PRIP 2025), pp. 176–179.
3. Kanstantsin Kurachka, Xuemei Wang. Automation of primary diagnostics of diseases of the human lumbar spine using intelligent analysis of ct images // 2025 Open Semantic Technologies for Intelligent Systems (OSTIS-2025), pp. 355–360.

ПРОЦЕДУРНАЯ ГЕНЕРАЦИЯ КОНТЕНТА

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Рассмотрена процедурная генерация контента, алгоритмы процедурной генерации, преимущества их использования в разработке программного обеспечения, области их применения, существующие подходы и методы их оптимизации.

Ключевые слова: алгоритмы, процедурная генерация, разработка программного обеспечения, оптимизация.