

PPCNet: Projection-Conditioned Point Cloud Reconstruction of Spinal Vertebrae from Biplanar Radiographs

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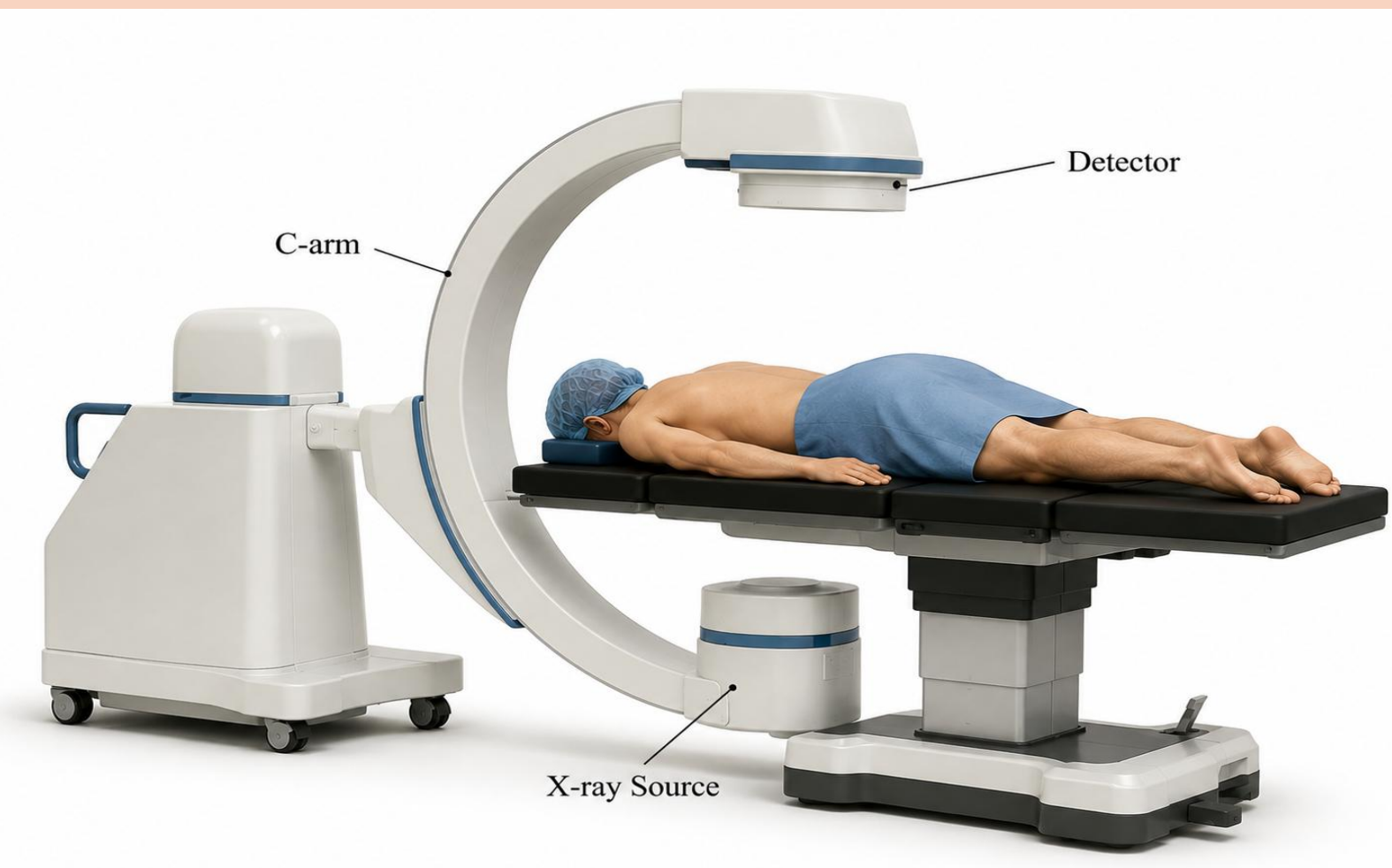
MLMI2026



Website

INTRODUCTION

- Minimally invasive spine surgery requires accurate intraoperative 3D visualisation; misjudging depth of a few millimetres can cause neural or vascular injury.
- Cone-beam CT is costly with high radiation; C-arm fluoroscopy is routine but captures only 2D projections without depth.



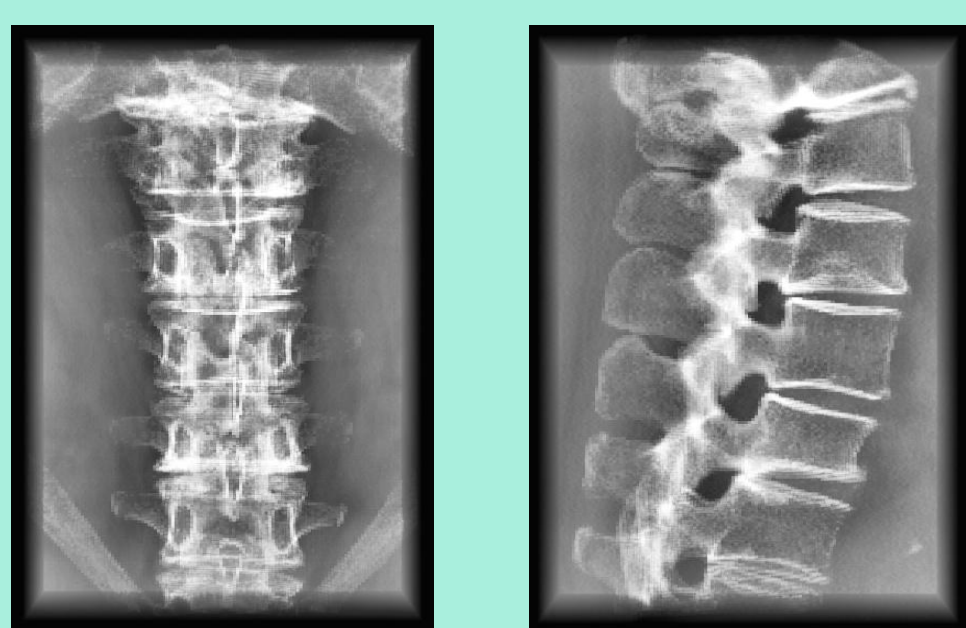
EXISTING LIMITATIONS

Approach	Limitation
Statistical shape models	Bounded by pre-defined shape priors, limiting patient-specific fidelity.
Volumetric deep learning	Fixed grids at ~1.5 mm/voxel; disc spaces (3-5 mm) span only 1-2 voxels.
Existing DL view fusion	Calibrated 3 x 4 matrices available, yet view correspondence learned implicitly.

DATASET

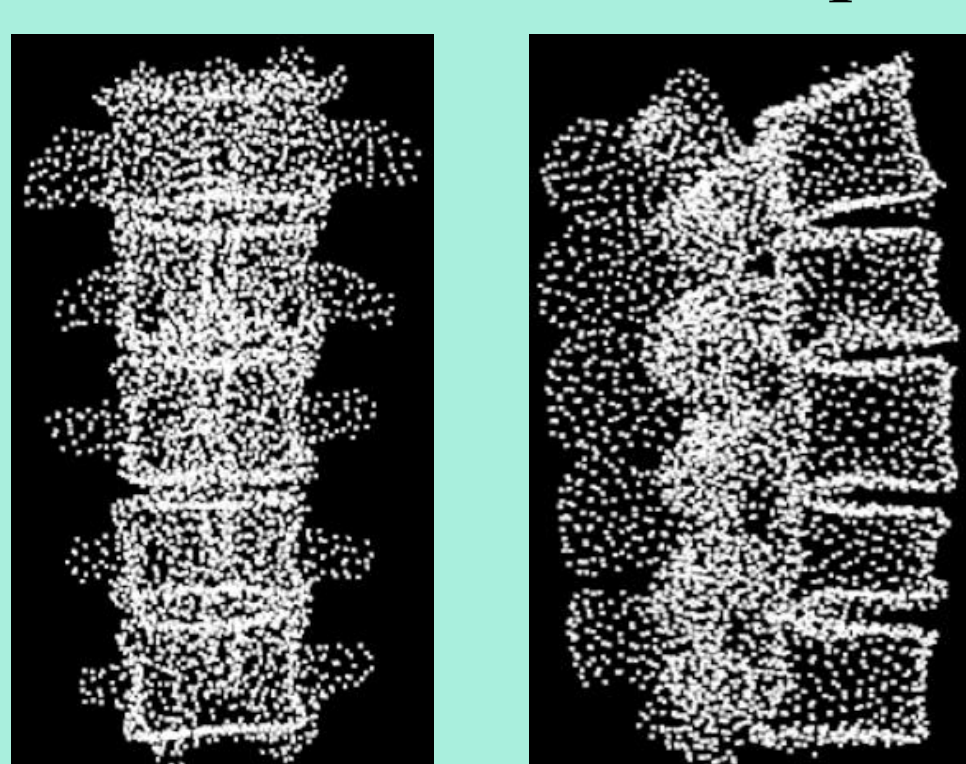
- 1,037 patients from VerSe and CTSpine1K (L1 to L5 lumbar); split: 829/103/105
- Biplanar DRRs (AP at 0°, LP at 90°) with calibrated 3 x 4 projection matrices.

Biplanar DRRs

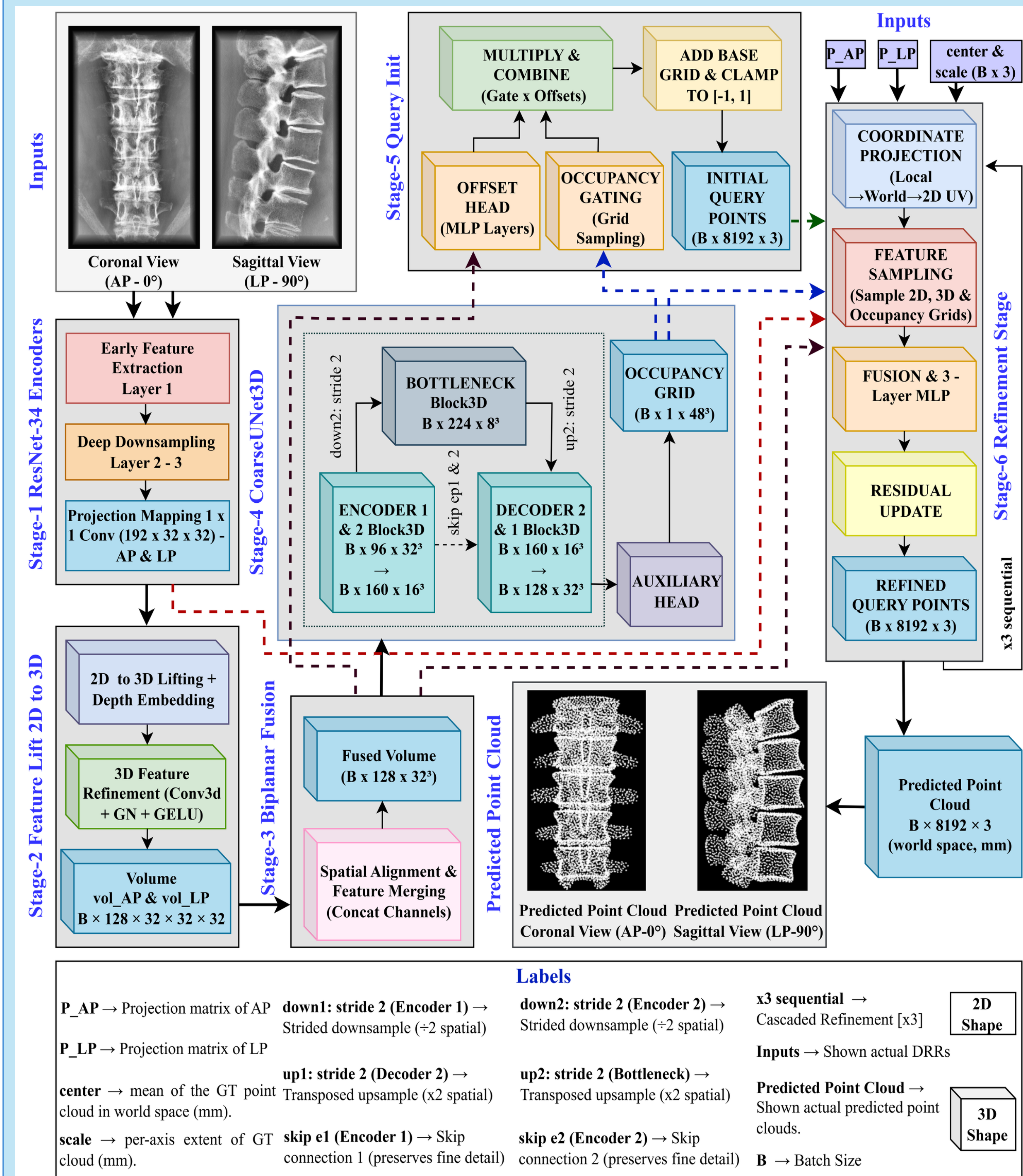


- Ground truth via farthest-point sampling.

GT Point Cloud

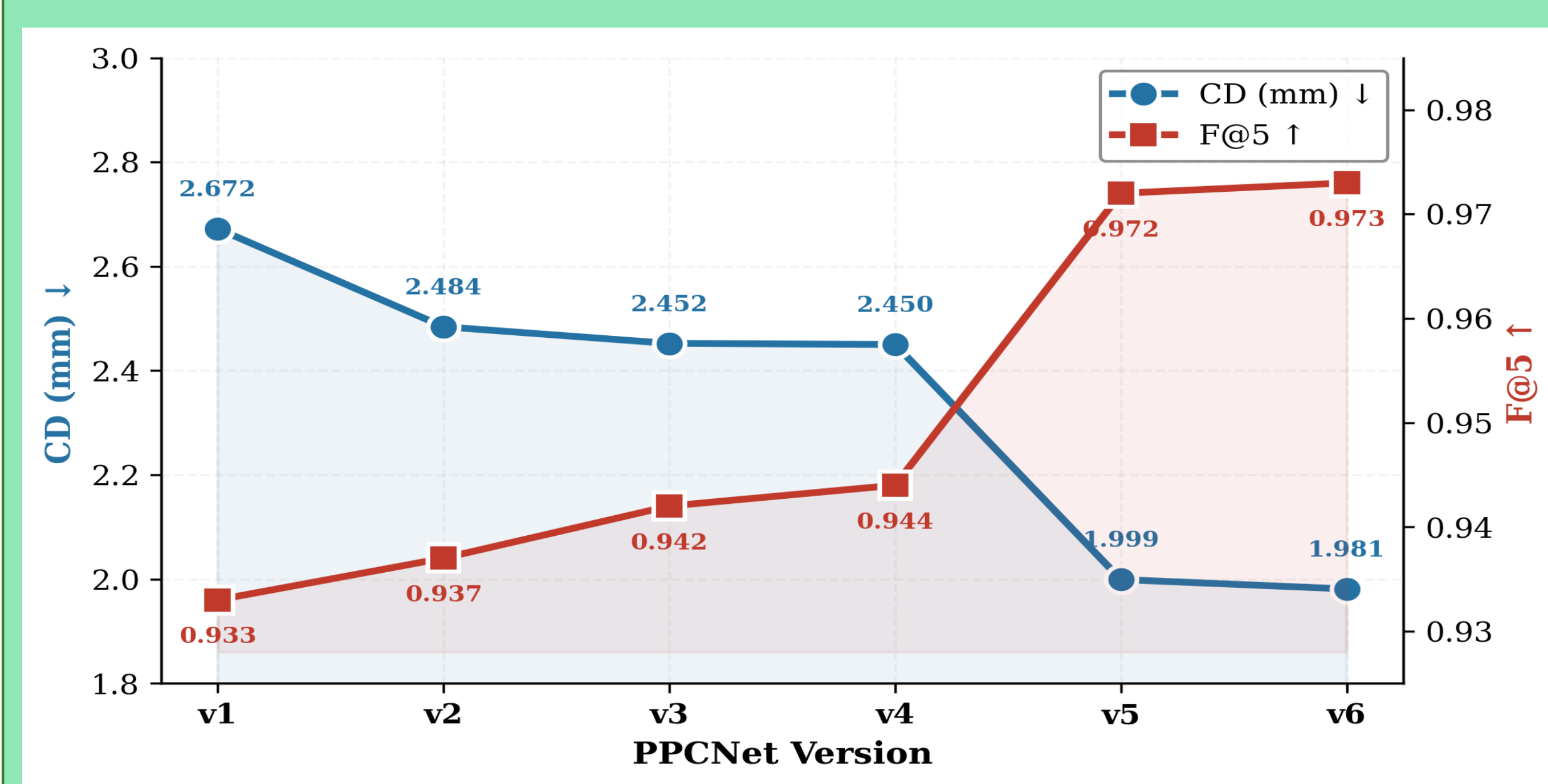
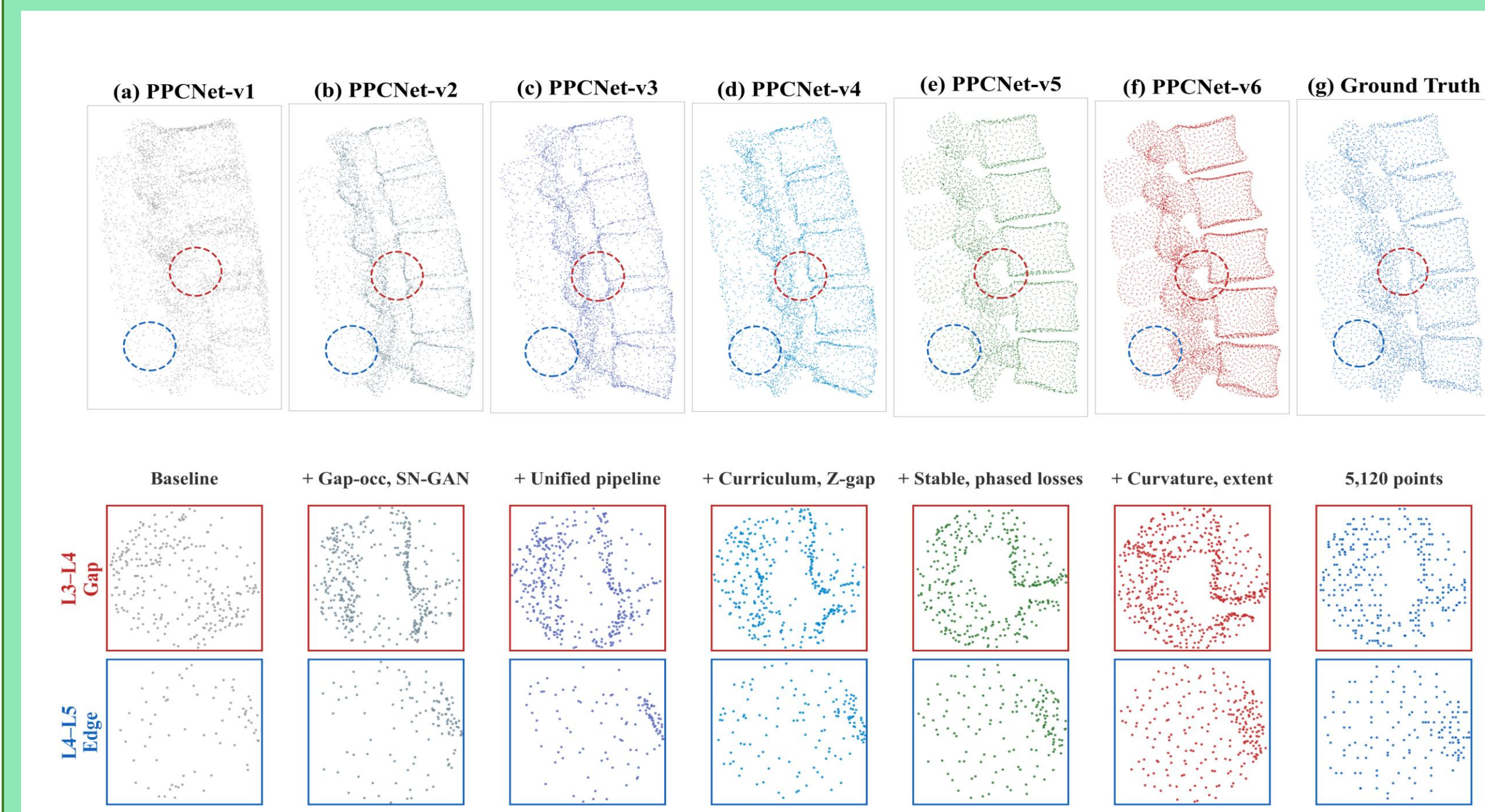


ARCHITECTURE

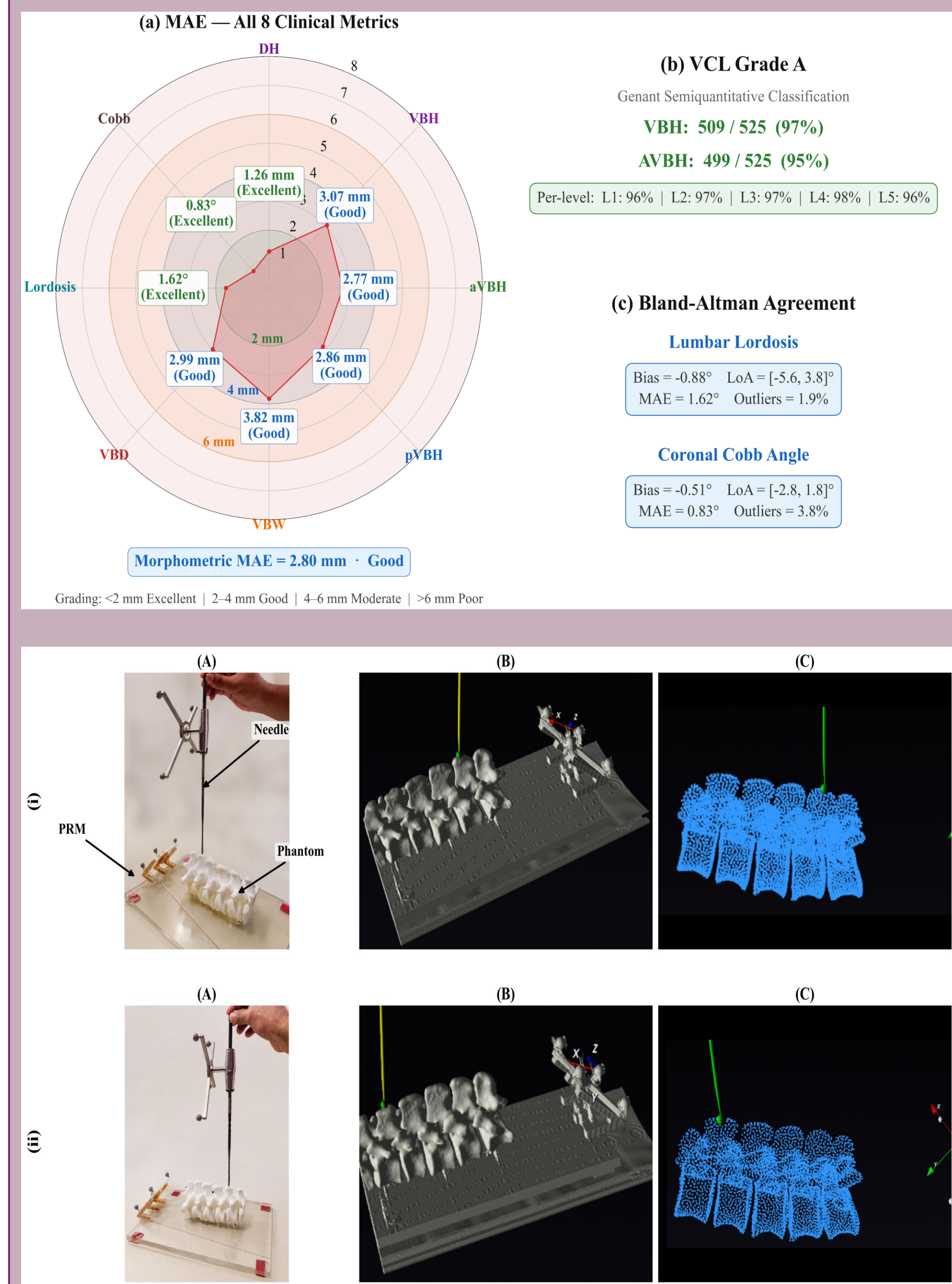


- Dual ResNet-34 encoders with occupancy-gated query initialisation; 520-d feature vector per query refined across 3 projection-conditioned stages (± 0.25 per stage).
- Training losses:** Chamfer, gap penalty (novel), axial density (novel), extent match (novel), curvature, occupancy, sliced Wasserstein, and projection Chamfer.

ABLATION



CLINICAL VALIDATION



BASELINE COMPARISON

All 4 baselines re-implemented on the same dataset and split.

Method	Params	CD (mm)	F@1	F@2	F@5	HD95 (mm)
X2CT-GAN	344.1M	2.489	0.079	0.444	0.933	6.624
BX2S-Net	23.2M	2.564	0.081	0.448	0.927	6.722
Swin-X2S	67.3M	2.475	0.081	0.449	0.937	6.576
3D-ReVert	38.4M	2.084	0.133	0.587	0.966	4.586
PPCNet (Ours)	38.6M	1.981	0.155	0.646	0.973	4.525

CONCLUSION AND FUTURE WORK

- PPCNet reconstructs L1 to L5 as 8,192 points from biplanar DRRs; 1.981 mm Chamfer distance, 2.80 mm morphometric MAE, 97% VCL Grade A, 3.01 mm navigation centroid error.
- Future work:** Bridging the sim-to-real gap with real fluoroscopic images; robustness under imperfect C-arm calibration.