

Nordic AI Meet 2026

P4: Machine Learning, Intelligent Systems & AI for Science and Engineering

10. From Spruce to Pine and Back: Bidirectional Transfer Learning for 3D Knot Segmentation in Softwood CT

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Abstract: Knots are the most decisive feature for the value of sawn timber. 3D computed tomography (CT) can map them inside a log before it is cut. Voxel level knot annotations are expensive and each knot is measured physically on stem sections to make it precise. So labelled CT datasets rarely cover more than one species and deep learning for this task has stayed confined to single species models. We study cross-species transfer for volumetric knot segmentation between Norway spruce and Scots pine, using a paired dataset of 1,536 3D CT volumes at 0.5 mm isotropic spacing. Our premise is structural, across species a knot shares a common pith-to-bark geometry and differs mainly in CT intensity, bark and tissue appearance, so the geometry should be shared and only appearance adapted. On a common 3D CNN (nnU-Net-style) backbone, we compare a single-species baseline against three strategies: standard fine-tuning, sequential transfer with source-anchored L2-SP regularization, and a species-aware joint model that shares the backbone and routes each species through small residual adapters and output heads and evaluated bidirectionally under one protocol. Source initialization alone transferred inconsistently, retaining source knowledge (via L2-SP or shared adapters) improved Dice in both directions and improved reliability, cutting the large boundary-error variance of the baseline (pine HD95 standard deviation 2.50 to 0.51 mm). The gains concentrate near the pith, the anchor point for downstream sound- and dead-knot measurement, delivered by a single model serving both species.