

Fabric-Elasticity Relationships in Cortical Bone

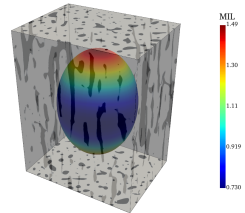
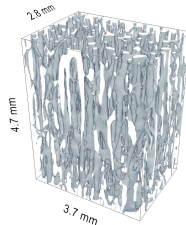
Mathieu Simon

February, 2025

Material

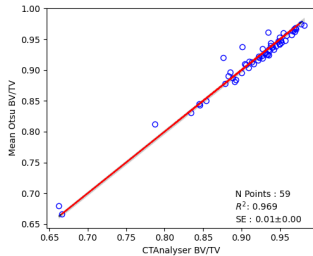
Data

- 59 scans
- 6.5 μm voxel size
- RUS measurements
- CTAnalyser

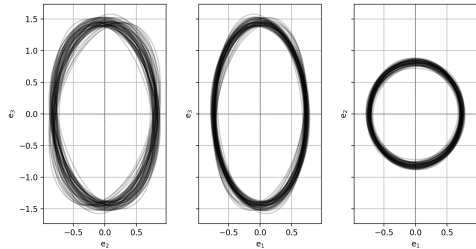


Segmentation

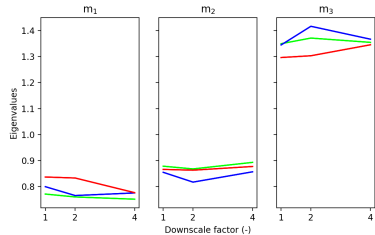
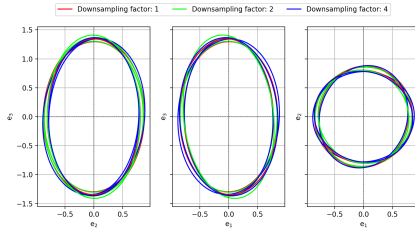
Mean Otsu threshold



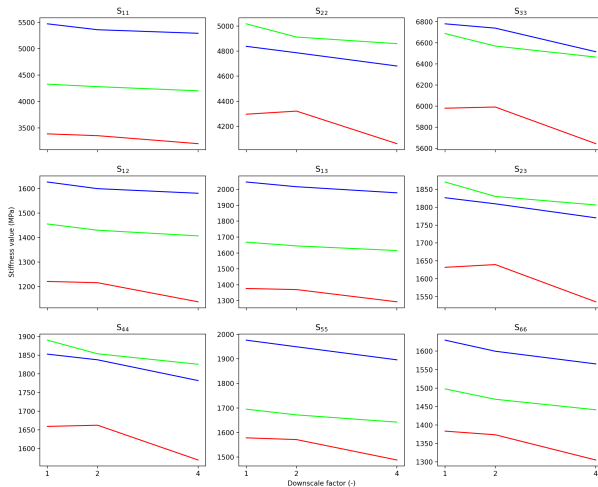
Fabric distribution



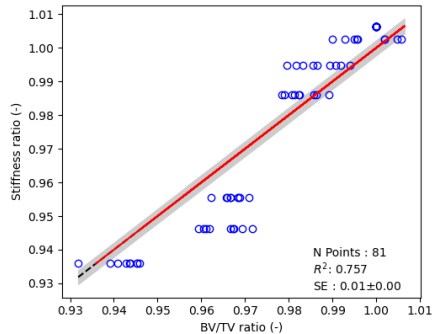
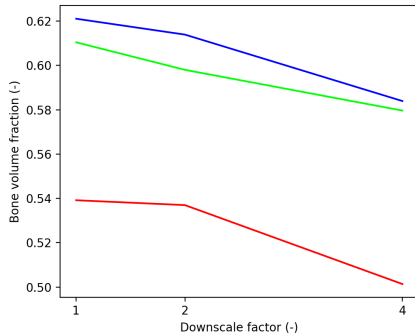
Resolution Effect - Fabric



Resolution Effect - Elasticity



Resolution Effect - Elasticity II

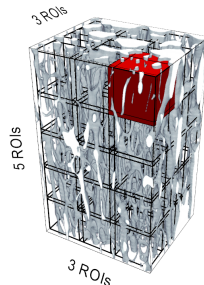


Convergence Study

Setup

- 1 mm ROI side length
- 3x3x5 ROIs
- 65 μm margin
- Groups of 1, 2, ..., 45 ROIs

→ $\sim 2^{45}$ possibilities

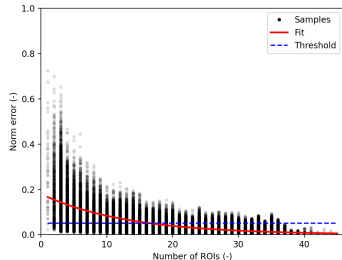


Convergence Study

Sampling

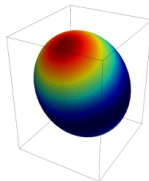
- Balanced clustering
 - Linear sum assignment
 - $216 \cdot 10^6$ possibilities
- N samples = 1000
- Norm Error
- Threshold = 0.05

→ 15-16 ROIs



Material Effect

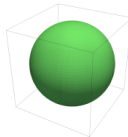
Structure



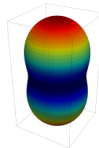
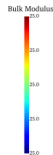
Fabric



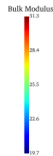
Material



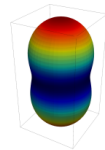
Isotropic



Transverse Isotropic



Mechanics

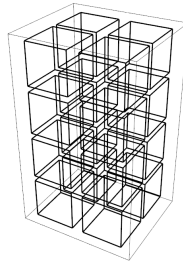


Transverse Isotropic

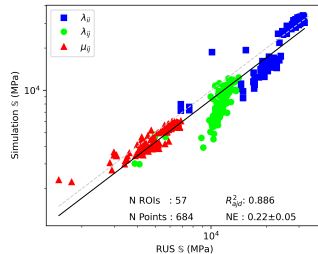
Homogenization

Setup

- Downsampling factor: 2
- $16 \times 1 \text{ mm}^3$ ROIs
- Isotropic vs transverse
- Mean \bar{S} / Sample

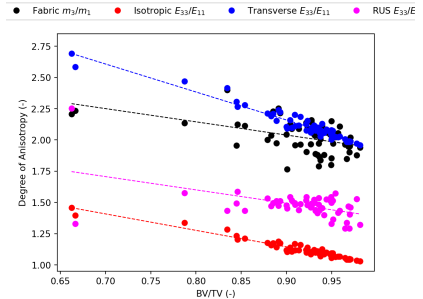
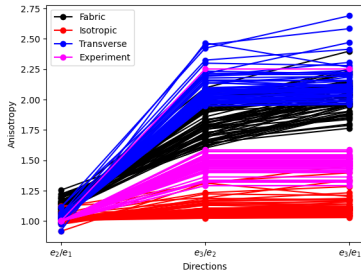


Isotropic Material

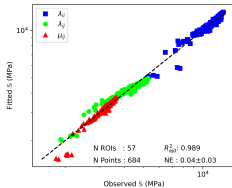


Transverse Isotropic Material

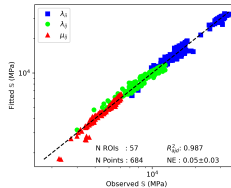
Anisotropy



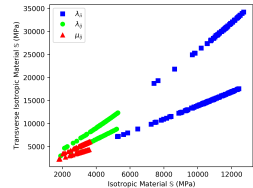
Homogenization



Isotropic



Transverse



Comparison

Comparison with Trabecular Bone

$$\mathbb{S}_{Ts} = \mathbb{S}_T / \|\mathbb{S}_T\| * \|\mathbb{S}_I\|$$

Study	Bone type	Resolution	λ_0	λ_0'	μ_0	k	l	DA
Gross et al.	Trab.	18	4609	3692	3738	1.60	0.99	1.67
Panyasantisuk et al.	Trab.	36	3841	3076	3115	1.60	0.99	1.54
Simon et al	Trab.	61	2738	1662	2187	1.60	0.99	1.99
Present study	Cort. (\mathbb{S}_I)	13	5389	5307	4023	1.60	0.99	2.02
Present study	Cort. (\mathbb{S}_{Ts})	13	5574	5511	3077	1.60	0.99	2.02

Comparison l Exponent

Reference: Transverse isotropic

- $S_{Is} = S_I / ||S_I|| * ||S_T||$
- $\lambda_0 = 11096$
- $\lambda_0' = 10970$
- $\mu_0 = 6124$
- $k = 2.18$

Matrix	Isotropic	Transverse
l	-0.04	0.46
95% CI Low	-0.12	0.39
95% CI High	0.04	0.52