Biomimetic Traction-Enhancing Scale Arrays enable Soft Robot Transitions by Offloading Computation into Morphology

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Nature-inspired soft robotic materials increasingly facilitate capabilities ranging from dexterous manipulation to multi-modal locomotion. Inspired by Pel's scaly-tailed flying squirrel—a highly arboreal West African mammal—we translate uCT scans of its caudal scaly organ into anisotropic micro-scale arrays in soft elastomeric composites, showing how biomimetic materials enhance traction-enhancing performance in scansorial locomotion including agile perching, not only increasing crash-landing robustness but simplifing robot control by offloading it into morphology. Directional 1 degree of freedom features provide friction anisotropy, passive energy dissipation, and load-activated interlocking that stabilize contact on uncertain substrates, reducing sensing/actuation demands during traversal, perching, and grasping. This work combines scalable multi-material additive manufacturing with machine learning-guided inverse design to tune tilt, pitch, and hierarchy for targets such as slip-onset angle, energy budget, wall-bound impact attenuation and control-effort reduction. Prototypes for soft perching/landing pads align with smart materials, multi-scale fabrication techniques, structured surfaces, and theory/modeling.