

The body-language of the elephant trunk

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The elephant proboscis (trunk) is a spectacular organ for delicate to heavy object manipulation as well as social and sensory functions. It is a muscular hydrostat, just like the tongues of reptiles and mammals, and the arms and tentacles of octopi and squids. These arrays of muscles can move with a virtually infinite number of degrees of freedom. They are capable of torsion, bending, elongation, shortening and stiffening, all without the support of any bone. Elephants have evolved unique biomechanical strategies to manage the complexity of their trunk. Behavioral experiments with objects of various shapes, sizes, and weights indicate that complex behaviors emerge from the combination of a finite set of basic movements. Curvature, torsion, and strain provide an appropriate kinematic representation to extract motion primitives from 3D trunk trajectories, which we obtained from marker-based motion capture measurements. In particular, the transport of objects involves the proximal propagation of an inward curvature front initiated at the tip. The trunk can also form pseudo-joints for point-to-point motion, momentarily resembling an articulated arm with an elbow and a wrist. Remarkably, the trunk tip velocity obeys a power law with its path curvature, similar to human hand drawing movements. Using medical scanning technologies and serial-sectioning, we analysed with unprecedented precision the functional morphology of the largest muscular hydrostat on Earth, allowing us to draw strong connections between its motion primitives and muscular synergies. Our study provides data for developing innovative “soft-robotic” manipulators devoid of articulations, replicating the high compliance, flexibility, and strength of the elephant trunk.